Macmillan's Geographical Series

MAPS
AND
MAP DRAWING

ELDERTON

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MAPS

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BY

WILLIAM A. ELDERTON

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to that most important part of geography for young students—the uses and the study of maps and globes.

The reader is supposed to understand the use of such common mathematical instruments as the compasses, the dividers, and the protractor; and to have some knowledge of elementary geometry.

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MAPS AND MAP-DRAWING

I.—HISTORY OF MAPS

Ancient Maps.—We are all more or less in the habit of using maps; they have become so completely mixed up with our thoughts of places far and near that we take their existence as a matter of course, almost in the same way as that of the sun above our heads or the air about us, and never think of how they came to exist at first, or how they are now constructed. The object of the following pages is to give some account of these matters.

To distinguish him from an animal, man has been defined in endless ways. If we described him as an animal that drew pictures, we should not have a bad description of him, for we should exclude all but men; and all men seem naturally to convey their thoughts by some sort of drawing. One of the first amusements of a child is to make a scrawl which he calls a house or a man, and the lowest savage seems to have some notion of describing objects by rough scratches on stones or wood or tattoo marks on his

person. The earliest forms of writing have been representations of things, such as the hieroglyphics of Egypt or the picture-writings of Mexico.

As soon as man took an interest in anything outside himself and his immediate surroundings, he would represent the relative positions of places by rough drawings; and this art grew up specially amongst those savages who wandered most, and therefore needed most to know the position of places. It was by such maps that the Eskimos helped Parry and M'Clintock in their Arctic explorations.

We have very early records of map-drawing amongst the Egyptians. Apollonius of Rhodes tells us of Egyptian maps on wood, kept as heirlooms, which had been made in the time of Rameses II, or about 1300 B.C. There is an old papyrus now in the Turin Museum drawn nearly fourteen centuries B.C., giving roads, and water with crocodiles and fish in it. Layard, the explorer of the ruins of Nineveh, discovered maps in Assyria. These, however, are only road plans, and hardly the germs of scientific maps such as the growth of the science of geodesy or earth-measurement has taught us to make now. But our present method is closely connected with astronomy, and in that science we know the Chaldeans and Egyptians were far advanced. It is held by some writers that the Pyramids, besides being tombs, were astronomical observatories. We are sure at least that the Egyptians could calculate the times of the re-

currence of eclipses, which is hardly possible if they had not known that the earth was a sphere. Again, we have derived our division of a circle into 360 degrees, each degree into 60 minutes, and each minute into 60 seconds, from the Greeks, and they received it from the Babylonians.

Hence we see that the fundamental principles upon which the science of earth-measurement has been built had their foundations laid amidst those ancient civilisations which excite greater wonder and admiration the more we learn about them. The Greeks certainly owed much of their science to the Egyptians, and they were the first, as far as we know, to attempt scientific map-making; that is, they first used observations of the heavenly bodies to determine the exact position of places with respect to one another, and so were able to join together plans of small spaces of land until they mapped out whole countries, and, as far as their knowledge went, constructed maps of the world.

The first step in this direction was taken by Anaximander (560 B.C.) He attempted to draw a map of the world; but, like the Greeks generally, he was inclined to form a theory in his own mind, and then make the few facts which he was able to collect fit in with it. His theory was that the lands of the world formed a circle, and that Greece was the centre of it; and in accordance with this notion he drew his map.

About one hundred years afterwards, Democritus of Abdera, who had travelled to the far East, perhaps

even into India, saw that this form could not be correct; but he could not quite break away from theory and depend on observations, of which, indeed, he had but a scanty supply at his command,—so he invented a world-map, whose breadth from east to west was half as long again as that from north to south.

From the time of Alexander the Great the Greeks were closely connected with Egypt, and so they borrowed more and more of its science. It was in the year after the death of that conqueror that a Greek voyager first made an observation of the latitude of Marseilles. The Greek philosophers of the school of Alexandria learnt that the earth was a globe; and Eratosthenes of Cyrene attempted its measurement. His views of the relative distances of places were much more correct, and he made use of a network of latitudes and longitudes. But it was the great astronomer Hipparchus of Nicæa (150 B.C.) who established the true principles of map-drawing when he showed that latitudes and longitudes should be calculated by astronomy. Crates of Mallus made the first globe; but he filled it in rather as he imagined it should be than as he had ascertained it was; for he placed a band of water all round the Equator, and then figured four semicircular continents on the rest.

Next we come to Claudius Ptolemy, the second greatest astronomer and the greatest writer on geography that Greece produced; he made a collection of the latitudes and longitudes of all known

places, calculated from the few which had been determined by astronomy. Unfortunately, a mistake made in one measurement caused an error in all his results. He himself constructed no maps, but the charts formed from his calculations still exist and go by his name. The most important errors in them are that the Mediterranean is too long, Europe too narrow, Asia extends much too far to the east, the peninsula of India is omitted, but Ceylon is vastly too large, Africa south of the Equator is too wide, and there is a mass of land to the south of the Indian Ocean. The general form is in other respects very fairly correct.

Maps in the Dark Ages.—Ptolemy's geography may be regarded as the highest point reached by the ancients; the Romans were not a scientific people, and though they made excellent route maps and plans of country for military purposes, they paid no attention to the scientific method of Hipparchus, and the knowledge even of the spherical form of the earth seems to have slipped away. Then came the fall of the Roman Empire, and with it the extinction of all science. The maps of the world during the "Dark Ages" are very grotesque, the general form is shown in the illustration (Fig. 1); but they were

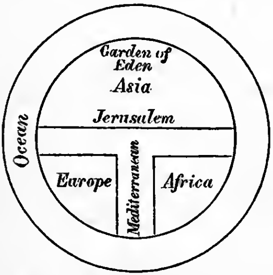


Fig. 1.—A "Mappa Mundi" or World-Map of the Middle Ages.

often decorated with much skill: Jerusalem, with towers and battlements, would be in the middle, and to the extreme east, which was made the top of the map, would be the Garden of Eden, with elaborate hedges, and Adam and Eve in the midst of it. The sea was drawn with waves, ships, dolphins, and whales. The Church had determined that the world was flat, and flat, therefore, it had to be.

But light broke at last. Marco Polo, the Venetian traveller, after visiting the great cities of China and Japan, returned to Venice in 1295, and during his imprisonment in Genoa wrote an account of what he had seen. His strange stories roused attention, and his observations were of great effect in breaking down the prevalent ignorance.

At the same time the use of the mariner's compass had become general, and the great mercantile cities of Italy had grown to be the carriers of the world; their fleets visited each well-known port, and their navigators constructed what are known as "compass charts"—from numerous points as centres they drew lines representing all the points of the compass, and then determined the positions of ports and capes by the intersection of two of these lines from different centres. Thus they obtained a fairly good map of the coasts of the Mediterranean.

Modern Maps.—With the "Revival of Learning" came the translation into Latin of the great work of Ptolemy in 1409, and its publication in 1475; and from that time his calculations and the charts made

from them were accepted as the great authorities. The accounts of Marco Polo and other travellers were grafted on to them, and the belief that the world was a globe soon gained ground, so that Columbus found the way prepared for him when he undertook his great enterprise.

Ptolemy's calculations having carried the Spanish coast too much to the west and China far too much to the east, Columbus expected the distance between them across the ocean to be much less than it is, and hence he believed that he had reached the East Indies when he landed in the Bahamas.

Each fresh discovery tended to make the new maps more complete and accurate. In 1544 Sebastian Cabot produced his map of the world, in 1569 Humphrey Lhuyd, a learned Welshman, published his map of England, and in 1575 a British Atlas of twenty-six sheets was brought out by Saxton. Mercator, whose real name was Gerard Kramer, was the greatest geographer of this time, and he produced and himself engraved numerous maps on a method of projection of his own, of which we shall have more to say hereafter.

The seventeenth century ushered in great changes. Bacon taught the true methods of research, and that all science worthy of the name must be fruitful of results useful to mankind. The telescope was invented, and Galileo in 1610 discovered the moons of the planet Jupiter. Cassini some sixty years later ascertained the laws of their motion, and thus pro-

vided us with an invaluable way of determining longitudes (see p. 43). The latter and his son and grandson were much engaged in geographical labours of great value—the first two in the measurement of an arc of the meridian from near Paris to Dunkirk, for the first time obtaining a nearly correct result; the last in superintending the great survey of France, completed in 1750.

Before the end of the century great improvements had been made in the instruments for taking all observations. Gascoigne, before his death at the battle of Marston Moor, at the age of twenty-four, had discovered how to apply a telescope to the sextant (see p. 44), and to use an arrangement of parallel wires in his telescope so as to measure small angles, by which means he had found the diameters of the moon and planets. But his early death prevented their publication, so that the first improvement had to be rediscovered by Picard and the second by Auzout. Huyghens applied the pendulum to astronomical clocks, which enabled observers to judge very correctly the exact time of an observation; and Rœmer invented the transit instrument, by which astronomers can tell exactly when a star crosses the meridian of the observatory.

These astronomical instruments were a great aid to geography, as they made our knowledge of the motions of the stars much more certain; and on this knowledge depend our methods of determining latitudes and longitudes.

The early part of the eighteenth century is chiefly remarkable for the progress made in determining the form of the earth. At a particular spot a pendulum of a certain length will beat once in a second of time; but it was found that at places having different latitudes the length of the pendulum had to be altered. This could be at once explained if the distances of the places from the earth's centre were not the same.

Again, mathematicians calculated that a rather fluid body spinning round its own axis would not take the form of a sphere, but of an oblate spheroid, or a sphere flattened towards the poles.

This was proved to be the true form of the earth by measuring accurately the length of a degree of the meridian at different latitudes. These distances were found to vary slightly just as was expected, increasing a little from the Equator towards the poles. Calculating from these measurements, the diameter of the earth at the Equator is judged to be 7925·6 miles, and at the poles 7899·2 miles.

The chief work of this century has been the making of great surveys, according to the methods and by the use of the instruments which science has devised for the purpose. When we come to describe a trigonometrical survey, we shall see better what these are. The Government of nearly every European country has undertaken this work. The United States and most of our colonies have followed the example; and even of half-civilised countries we

have more or less complete surveys by private efforts. The coast line of every known land has been laid down with great care on our Admiralty charts; and, as every explorer in the wildest districts can be provided with instruments for observing, and instructions how to use them, our stock of knowledge of the interiors of strange lands is now fairly complete, and each year some dark spot is rendered light. Still, there remain dark spots, and to bring them to light is now the chief duty of the geographer. To follow in the steps of the heroic travellers of the past, and, regardless of comfort and safety, to imitate with open eyes and minds the examples of such men as Cook, Mungo Park, Livingstone, and Stanley, will be a work worthy of the adventurous spirits of the future, and will complete that which is now so far advanced.

We shall now proceed to consider the way in which the necessary facts for map-making are obtained, and then how globes and maps are themselves constructed.

II.—SURVEYING

If we found ourselves in an unknown land, and had to give a full account of it, besides describing its products and people, we should wish to draw a plan of it, which would show the form of its coasts, the course of its rivers, the situation and height of its hills, and the relative positions of all points of interest. To do this the district must be measured and then drawn to some known scale. It will clear our way if we understand something about these scales.

Scales.—If we were going to draw a plan of a room, we should measure the sides, and then draw lines of proportionate length to represent them. We might take a line half an inch long to represent a foot, so that, if our room were 18 feet long, a line 9 inches long would mark its length on paper: as there are 24 half-inches in a foot, it is clear that our plan will have every line in it one twenty-fourth of the length of the corresponding line in the room. The scale would then be called the scale of $\frac{1}{24}$; and this fraction is known as the *Representative Fraction*

of that scale which is one twenty-fourth of the natural size.

Of course, in drawing plans of large plots of ground, farms, estates, or parishes, we must draw them on a very much smaller scale. If we were to take one inch to represent 100 yards, since 100 yards contain 3600 inches, the scale would have the representative fraction $\frac{1}{3600}$, but this would be much too large for any but small pieces of ground. If we drew a map of Rutland, the smallest English county, to this scale, we should need a sheet of paper 8 yards long and nearly as broad.

A very convenient scale for ordinary purposes is that chosen for the Ordnance Maps of the British Isles, which has a representative fraction $\frac{1}{63360}$, or represents a mile by an inch. Civil and military engineers, however, need maps to a larger scale than this; they make use of scales of 3, 6, 8, 12, and even more inches to the mile. In our atlas maps, again, the scale is much smaller; that of England in the Royal Atlas is 14 miles to the inch. On a globe with a diameter of 2 feet the scale is about 330 miles to the inch, and its representative fraction would be $\frac{1}{21000000}$. On every good map there is given the representative fraction of it, and scales drawn to show what lines represent certain useful measures of length, such as statute miles, nautical miles, kilometres for a map of France, or versts for one of Russia.

As an example of how scales are calculated and drawn, one might be prepared for the map of France

on p. 115. The side of the dotted square on it is known to represent 380 miles, and if we measure the distance on the map we find it to be 1·73 inch; then one mile would be represented by 1·73÷380 inches, or very nearly ·00458 inch; and 500 miles would be shown by a line 500 times this length, or 2·29 inches. We draw a line of this length, and divide it into five equal parts (Fig. 2). To do this we draw a line from one end of it, making any angle with

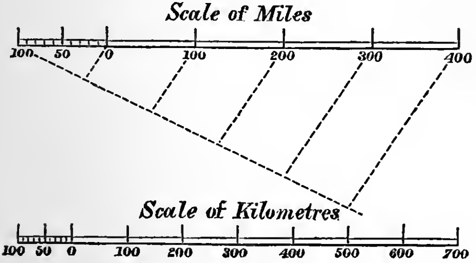


Fig. 2.—Comparative Scales of Miles and Kilometres.

it, and from this cut off any five equal parts, join the last of the points marked off with the other end of the given line, and through the other points draw straight lines parallel to this. Each of our divisions will represent 100 miles. We divide the first into ten parts, each of which will show 10 miles by the same method, and then finish off the scale as shown in the illustration.

If what is called a "comparative" scale of kilometres were needed we should proceed as follows.

Since a kilometre is 1094 yards, and a mile is 1760 yards, a kilometre is $\frac{1094}{1760}$ of a mile, then $\frac{1094}{1760}$ of ·00458 inch would represent it; this when worked out will be found to be very nearly ·00285 inch; hence 800 kilometres would be shown by 2·28 inches. We draw this line, divide it into eight parts, each of which is 100 kilometres, and the first into ten, and then complete it as in the previous scale.

The Vernier is a kind of scale used in some instruments described farther on, which may be explained here. Supposing we have a scale AB (Fig. 3), divided

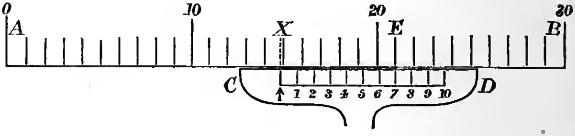


Fig. 3.—The Vernier.

into thirty parts, which are too small to be each divided into ten, but yet we want to measure tenths of these divisions; we can do this by means of the vernier CD, which is a movable scale. We should have an index on it shown by the arrow-head; and from this a distance of nine divisions of the original scale would be measured, and divided into ten equal parts. If we wished to measure a distance AX we should place the index opposite X and look along to the right until we saw that a line on the original scale coincided with one on the vernier; in the illustration this is at E. Now each division of

the vernier is nine-tenths of a division in the original scale, then the difference between the lines next on the left to E will be one-tenth of the original divisions, between the second pair from E two-tenths, and so on. But the index is seven divisions of the vernier off E, then it differs from the seventh division on the first scale by seven-tenths. Hence the distance AX is $14\frac{7}{10}$.

To most of us the only familiar use of the vernier is on the mercury barometer. We wish to determine the exact height of the mercury, and screw up or down the index on the vernier till it is in the same line as the upper surface of the mercury. This is exactly on the same principle as the illustration we have given, but has a little difference in the way of managing it, for instead of nine divisions being measured on the vernier from the fixed scale, eleven are taken, and these divided into ten parts; then each division on the vernier is $1\frac{1}{10}$ of the divisions on the scale.

In the sextant and theodolite (pp. 27, 45) we shall find that a circle is graduated to half degrees, and a vernier enables us to measure accurately single minutes; for this purpose the vernier will be an arc of 29 or 31 minutes, and will be divided into thirty equal parts.

Surveying by Eye.—Returning now to our unknown land, we will consider how to measure it. Supposing it a small slip of land, if we had no instruments to help us we might make a rough sketch of

its form by counting our steps in walking straight from one end of it to the other, and judging by the eye the distance of the boundary on each side of our route at various points in it.

After making a convenient scale of paces, we should draw a straight line representing, according to the scale, the whole length paced; and we should mark the points on it at which we had observed the boundary; we should then set off on the proper side of the line distances from the scale corresponding to the observed distances; and joining all the extremities, we should have our sketch.

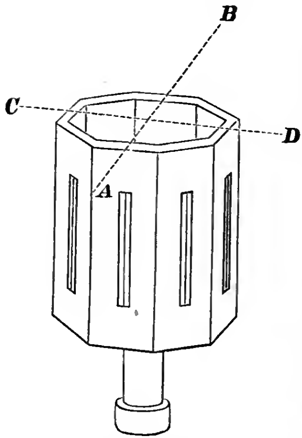


Fig. 4.—Cross-staff.

The result would be very rough indeed, but understanding it will help us to understand the more accurate methods to be now described.

Surveying by Chain and Cross-staff.—We will suppose our ground to be a small island, and we will measure it as a surveyor would plan a few fields. We shall be provided, as he would be, with a *Gunter's Chain*, measuring 22 yards in length, and formed of 100 equal links, and ten *arrows* or pins of steel to mark

places on the ground; and we should have a *cross-staff* (Fig. 4)—that is, an upright staff having a hollow metal head, with vertical slits having hair lines or thin wires down the middle of each slit, the slits being so arranged that two pairs of them give directions at right angles to one another, as AB and CD on the figure. We should also have a *tape line* or *offset-staff*, ten links long, to measure short distances,

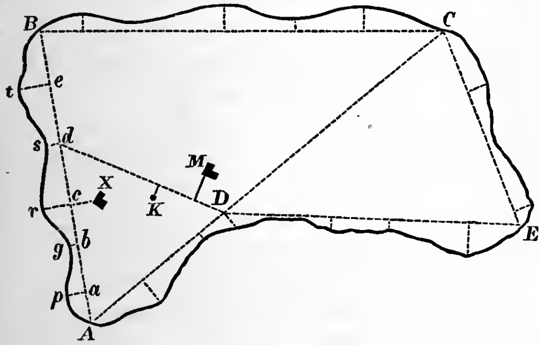


Fig. 5.—Surveying by Chain and Cross-staff.

and a *field-book*, which is a note-book with two parallel lines ruled down the middle of each page.

Supposing our island were of the shape shown in the illustration (Fig. 5), we should divide its surface into triangles, taking care to make them as large as possible, and with their sides nearly equal and as close as possible to the shores. If ABC and CDE were the two triangles decided on, we should mark the five points A, B, C, D, E, which are called

stations, whilst the sides of the triangles are called *traverse lines.*

Starting at A, we should enter in our field-book at the bottom of a page "from A go to B." We should then with the chain measure along the direction AB until we were near the point *a*. We should then place our cross-staff in the ground and turn it till looking along one pair of slits we see B. If, when we look along the slits at right angles, the point *p* is visible, we have determined the position of *a*; if not, we must move our staff a little forward or backward till it is so. The chain determines the distance A*a*, which we enter just above our first entry in the field-book, and in the middle column. We next measure *ap*, which is called an offset, by tape or offset-staff, and enter the distance on the left of our middle column and in a line with the last entry. We now go on with our chain measurements to *b*, *c*, *d*, *e*, and B successively, entering at each point its distance from A and the length of the offset.

We proceed in the same way along each of our traverse lines. To determine the places of objects within the triangles not near enough to be determined by offsets from our traverse lines, we might take other lines such as *d*D, which would enable us to determine K and M. Such lines as these also give us a test of the accuracy of our work.

There now remains only the work of drawing our plan, or *plotting* it, as it is called, from the notes in the field-book. Having drawn a scale of chains and

links, we lay down a line to represent AB; we measure the distances representing AC and BC with a pair of compasses, and draw arcs of circles with the centres A and B to intersect, which point of intersection is C. We measure off CD, and similarly mark E. We then measure the offsets, draw them, and joining their extremities, we obtain the coast line and the positions of the other points we have noted. Thus we should have obtained a very fair map of our island.

Now this method of surveying requires much time; and, though enabling us to fill up our plan very fully, it would be inaccurate if carried out over large spaces of country. We will go on then to consider how we should proceed when time is short and the spaces large.

Military Surveying.—There is an important system, differing in some respects from all others, made use of by military surveyors; and as this is a good introduction to what is understood as a trigonometrical survey, we will consider it here. The commander of a force has, we will suppose, unsatisfactory maps—that is, maps whose accuracy cannot be relied on, or which do not give those details which are required for military operations. He sends out men to examine and report on the country; and they proceed separately along the roads, or along fixed directions over open country, and make all their observations from these lines.

Sometimes they are provided with a *prismatic*

compass, as it is called, sometimes with a *plane table*, and often, in minor expeditions, they have to sketch, and it is astonishing how accurately this can be done, without instruments at all.

The Prismatic Compass (Fig. 6) is a small and portable instrument containing a magnetic needle moving a card on which are marked the 360 degrees into which

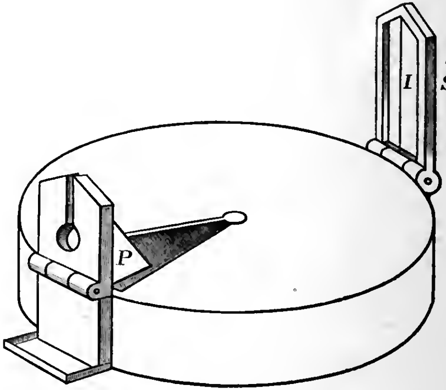


Fig. 6.—Prismatic Compass.

a circle is divided. There is a glass prism P on one side of it, and on the other a sight S, with a vertical hair line I down the middle. The surveyor is by means of this prism able at the same glance to see the distant object whose direction is required and a reflected image of the degrees by which that direction diverges from the north on the compass.

The surveyor proceeds from a fixed point in a

direction, which he accurately observes, straight to another point, and counts his paces or those of his horse. On his field-book he enters at the bottom of a page I for his first station, and the direction of his advance just above it, given in degrees observed with his prismatic compass.

As he proceeds he observes and registers the directions of objects on the right hand and left which it is expedient to note, entering carefully the distance from his first station at which the observations were made, and the total distance to the end of his first straight line of advance. This brings him to his second station, where his direction is altered, and from it he again advances, making his observations and entering them exactly in the same way. The distance of objects near his line, say up to 100 yards, will be judged by the eye, but for each more distant object he must make *two* observations at least by his compass from different points on his route. And so he proceeds as far as is required.

On his return to headquarters he draws out to a convenient scale a plan from his observations. Having noted two different directions to each distant object, the two lines he draws by his protractor on the plan representing these two directions will intersect at the point on the plan representing the position of the object.

The illustration (Fig. 7) gives a page of the field-book, and Fig. 8 the plotting of that page. The surveyor comes home with his notes, and on his paper draws the

line with the arrow-head as the direction which he is going to take as the north of the compass. He marks station I on his paper, draws a line to the north, and then draws with his protractor the line to station II at an angle of 77° to the east of north; and we here notice that the circle is graduated in the same direc-

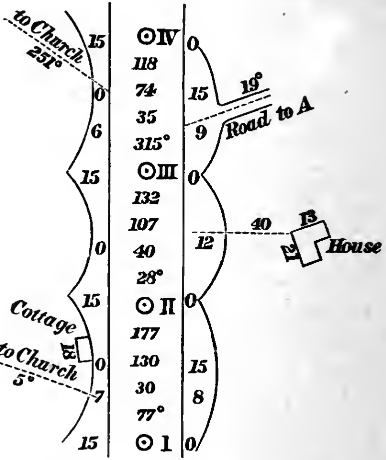


Fig. 7.—Surveying with Prismatic Compass.

tion as the numbers on the face of a watch, so that the E. of the compass will be 90°, the S. 180°, the W. 270°. Along the line he has drawn he measures 177 yards from his scale, which he knows to be the distance between I and II, as it is in his field-book immediately below station II. At II he draws the north line and the angle 28° from it, he measures

132 yards along this line to III, and similarly draws the line to IV.

Having thus plotted his traverse lines, he fills in the details. The curved lines on each side of the central column represent the sides of the road along

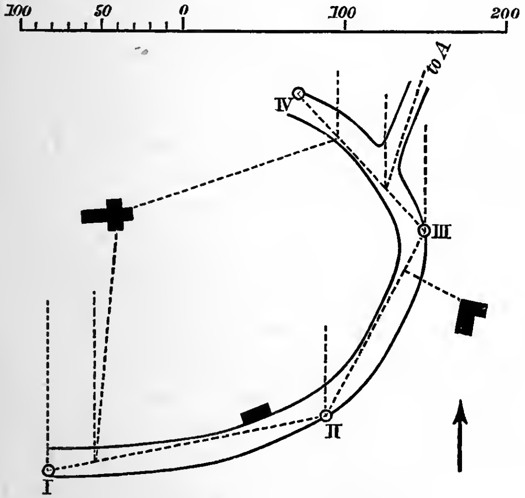


Fig. 8.—Surveying with Prismatic Compass.

which he has been moving, and the numbers between them and the ruled lines are the distances of the sides of the roads from the traverse line at the points given in the central column; thus at I he was close to the right-hand side of the road, which is 15 yards wide; when he advanced 30 yards he was 8 yards from the right and 7 from the left side

of the road, and here he observed the direction or "bearing" of a church steeple to be 5°; he will now plot these as shown in the sketch; he will mark 130 yards from I, and draw in the cottage beside the road, which he has measured as 18 yards long. He will next deal with the details along his second and third traverse lines, and the position of the church will be determined by the two observations of its bearing made at 30 yards beyond I and 74 yards beyond III.

In fine weather the method of the Plane Table is better, but takes longer, and must be used on foot. The plane table is a flat horizontal drawing-board supported on legs. The surveyor has a *declination compass*—that is, a magnetic needle in a rectangular box, the side of which is parallel to the needle when pointing to the north. He has also a ruler having bevelled edges and fitted with sights.

Placing the board in front of him, and drawing a line to show the direction of the magnetic north by his compass, he observes by sights on his ruler the direction in which he is going to advance from his first to his second station, and draws the line representing this direction. He now advances, counts his paces, and draws from points on his drawn line, marked off according to a scale of paces, the directions of all objects as he comes to convenient points for observing them. When he has reached the second station, he will set his board by placing his compass against the line giving the magnetic north and

shifting the board until the direction of the needle is exactly parallel to this line. He will then draw the second line of advance and proceed as before.

It will be noticed that the principle of determining the positions of objects is the same in the two methods, but that whilst with the former method the observations are only registered and afterwards drawn, with the latter method the observations and drawing are done at the same time.

We may here remark that the prismatic compass is a very useful instrument for explorers. A traveller in unknown districts cannot be burdened with elaborate instruments, nor has he time for careful observations, but he can by it determine roughly the direction of his journey and the position of a distant mountain top, as during a day's journey he will be able to get at least two observations of its direction, and can usually form a near guess at the distance he has travelled between the two.

It has, however, one great disadvantage—the presence of unsuspected iron will often render its indications quite worthless. Again, it requires a good deal of care to allow correctly for the *magnetic variation*, as it is called; for the magnetic pole, or that place in the Arctic Regions to which the magnetic needle points, is not only far from the true pole of the earth, but is constantly though slowly changing its position. He will then have from time to time to observe by how much the magnetic north varies from the true north, determining the latter by

observations of either the pole star or of the sun, and noticing the degrees between this and his magnetic pole.

Trigonometrical Surveys.—We can now proceed to the more exact and elaborate methods made use of in the great surveys of countries, which are done by governments, and take hundreds of surveyors and many years of work. The important mathematical science known as trigonometry was originated for this work; and the most elaborate and delicate instruments have been constructed to assist observations. It would be out of place here to describe these except in the most general way; it is more the principle than the execution which we inquire about now. One instrument, however, is so much used that we must try to understand its construction.

The Theodolite (Fig. 9) is an instrument formed of a telescope T attached to a vertical circle C, whose edge is graduated, the divisions showing degrees and half degrees. This circle moves on an axis supported on four legs, which rest on a horizontal circular plate P, which again rests on another circular plate Q, rather larger but with the same centre, and the first able to revolve on the second. The edge of the lower plate is graduated into degrees and half degrees, and these divisions can be subdivided into minutes and even less by a vernier V on the edge of the upper plate. There is a compass box B fixed on the middle of the upper plate and between the legs; and the instrument is provided with spirit-levels set in directions

at right angles to one another. The whole stands on a tripod arrangement (omitted in Fig. 9) rather like that commonly used by photographers. There is an elaborate arrangement of screws, etc., which enables us to level the plates with extreme accuracy by observing the spirit-levels S. When the plates have

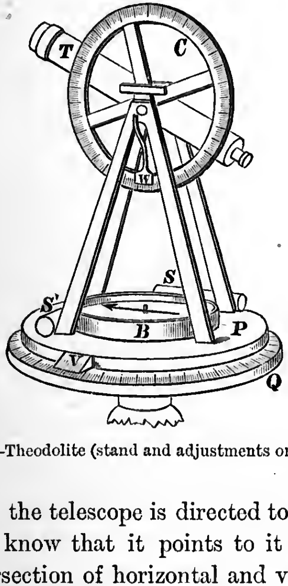


Fig. 9.—Theodolite (stand and adjustments omitted).

been levelled, the telescope is directed to some distant object. We know that it points to it when we see that the intersection of horizontal and vertical spider lines placed in the telescope are in a direct line with the object. We now look at our vernier on the upper plate and see the exact number of degrees and minutes registered on the graduation of the lower

plate. We then move the upper plate and telescope round until the latter points to a second distant object at the same height or elevation, as it is called, as the first, and again observe the number of degrees and minutes. The difference between the two observations determines the horizontal angle between the directions of the two objects.

Supposing we wish to determine the *vertical* angle between two distant objects which are so situated that one appears exactly above the other. We revolve the plate until the telescope points to the line joining the objects; we raise the telescope until the spider lines cross on the upper object, then we observe the angle on the circle C by means of the vernier W; then lower the telescope and observe the angle for the lower object; and the difference between the two is the vertical angle between them.

Now if we require the horizontal and vertical angles between two objects which appear neither to be of the same height nor one immediately above the other, we can do it by finding a point directly below the higher and at the same height as the lower.

We have thus roughly shown how the instrument is used to determine the horizontal and vertical angles between two objects; it can also be used, by the help of the compass on the upper plate, to determine the "bearing" of a distant object—that is, to read the angle between the direction of the object and the north of the magnetic needle; or it may be used instead of the *spirit-level* to determine the height of

all points within view of the same spot; for when the plates have been set horizontally the telescope can be fixed parallel to it, and its direction will then be horizontal, however far we revolve the upper plate.

The illustration (Fig. 9) gives the instrument in a much simplified form; the stand for the lower plate, with the screws and socket-joint by which it is levelled, and the microscopes for viewing the verniers, besides many other details, are left out to avoid confusion.

We have seen how the position of a distant point can be determined by noticing where two lines drawn in different directions from known points intersect. The known points and the distant one form a triangle; and those who are acquainted with the elements of geometry will see at once that a triangle having two of its angles and the side between them known, is known in every respect; and that different triangles with two angles in one of them equal to two angles in the other are exactly similar—that is, that their corresponding sides bear the same ratio to one another. Hence, when we know a side and two angles of one triangle, and draw another with the same angles and a corresponding side, bearing whatever ratio we choose to the known side, the other two sides will bear the same ratio to the sides of the known triangle. Hence a map drawn thus will truly represent the triangle that has been surveyed.

This is the principle made use of in all surveys; but in the foregoing pages we have supposed the

remaining sides to be drawn and their lengths to be determined by measuring them on the plan. The great disadvantage of this method, however, is that the best draughtsman in the world, provided with the best drawing instruments ever made, cannot by this method draw a plan of a triangle with a side really long, say 8 or 10 miles long, so accurately as not to make an error of yards in the other sides; and such an error as this in a large survey, where triangles are built upon one another, would soon become larger and larger, till he could not at all depend on his map being really accurate.

We therefore have recourse to trigonometry, which teaches us how to calculate by numbers the lengths of the other sides when we know one side and the angles, or two sides and one of the angles; and these calculations can be made so accurately that we shall obtain the lengths of the sides to within a few inches, and this with very little trouble.

The great distinction, therefore, between ordinary and trigonometrical surveys is that the former are *graphic* or depend on drawing, the latter are *mathematical* or depend on calculation.

The first step in a trigonometrical survey is to measure and remeasure with every possible precaution for accuracy a *base line*—that is, a straight line of considerable length on a level surface within the district to be surveyed. The angles between this line and various distant objects are accurately observed from its two ends by the theodolite, and the sides of the

triangles are calculated. Thence, taking these sides as fresh bases, other places farther afield can be determined, and so on till the whole country is mapped out.

The details will be filled in by "traversing" in a way similar to that given as the military method, but the measurements are made with the chain, and angles are usually determined by the theodolite; sometimes, however, the "plane table" is used.

Measuring the Base.—There are a few points well worth considering more fully. It is an understood principle in a good survey that the original triangles should be large; thus, in the great survey of India, their sides varied from 30 to 60 miles; but it would be almost impossible to measure accurately a base of anything like this length—perfectly level ground could hardly be found extensive enough, and the time taken would be very great, if it were carried out with the extreme care necessary.

When a flat extending for from 4 to 10 miles has been found, a mark is set up at each end, and the distance between them or "base" is measured, not with the rough chain of the surveyor, but with what are called *compensation bars*, which are so constructed that they remain the same length at all temperatures. If chains or plain steel or wooden bars are used, the temperature must be considered, and an allowance made for it; and this is very difficult to do, especially if the temperature is varying.

Then, again, the base is measured several times, and an average of the results is taken, since, however great may be the care observed, some very slight differences between them are sure to be detected.

Observing the Angles.—Each angle is likewise measured several times by the most elaborate theodolites. For ordinary surveying the lower plate of the instrument is only 4 or 5 inches in diameter, but those used in the Indian survey varied from 24 to 36 inches; their weight was such that, in moving from station to station, they were taken to pieces and, for safety, always carried by men. At many of the stations towers were built of masonry, on which to place the instruments for observations.

Again, several bases are usually measured, and a fresh triangulation is worked out from them to verify the work, by calculating thence some distance worked out from the original triangulation, and the results are known to be true if they agree.

The accompanying figure (Fig. 10) shows how from a small base AB a few triangles all of the best shape, that is, nearly equal-sided, enable a side of a large triangle to be found. From the base AB, by observations at A and B, the triangles ABC and ABD are calculated, thence CD is determined; with DC as base, the triangles ECD and CFD, and thence EF are worked out; then from EF as base, EGF and EHF are solved, thence GH is obtained, which by measurement will be found to be more than five times as long as

AB. Hence, if the base had been 6 miles, GH would be more than 30 miles long.

It will be noticed here that in finding the new base we have in several triangles different known

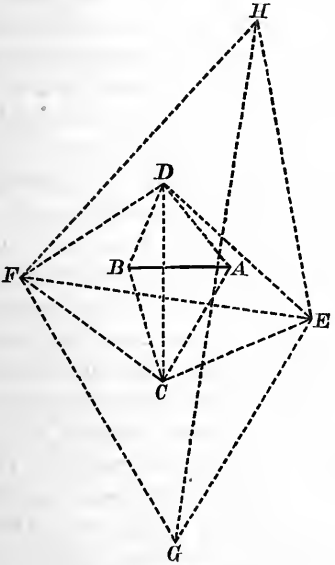


Fig. 10.—A Base Line and Triangulation.

facts to start upon from those we have had previously. For instance, CD has to be calculated from the triangle CAD, in which we knew the angle CAD and the two sides which contain that angle, viz. AC and AD. This brings in the principle of a triangle being known in every way under the same circum-

stance as those considered by Euclid in the fourth proposition of his first book.

Form of the Earth.—In describing a trigonometrical survey we have not yet taken into account the roundness of the earth. We learn from our books on geography that the earth is a sphere, or more correctly speaking, an oblate spheroid—that is, it is a sphere slightly flattened towards the poles; but this flattening is so slight that in making globes or drawing maps any allowance for it is quite unnecessary, indeed impossible. A two-foot globe, such as we have mentioned in explaining scales, would be a large one, yet since the diameter of the earth at the Equator is about 26 miles more than at the poles, and on such a globe about 300 miles would be represented by one inch, there would be less than one-tenth of an inch difference between the corresponding diameters of the globe. For our present purpose, therefore, we may consider the earth to be a sphere.

We speak of a ball as perfectly round if its roundness everywhere is the same, but this is not a mathematical definition of a sphere. There are two ways of defining it: we may call it a solid body the distance of every point on whose surface from the centre is the same, or we may describe it as a solid formed by a semicircle revolving round the diameter on which the semicircle is drawn.

Great Circles.—Both these definitions are of use to us. From the first we can see that if a sphere is cut through the centre in *any* direction by a plane

or flat surface the curve on the plane where it meets the sphere will always be a circle, and in whatever direction the cut is made that circle will be of the same size. Such a circle as this is called a *great circle.*

Small Circles.—From the second definition we learn other important facts. If NAS (Fig. 11) were a semicircle, and were made to revolve round and round NS, it would form a sphere. AOB has been drawn through the centre O at right angles to NS, and through any point P PMQ has also been drawn at right angles to NS. When the semicircle is twisted round, the point A travels round and round at the distance OA from O, always remaining equally distant also from N and S. When it has travelled to B and back to A it will have marked out a circle on the surface of the sphere, which is called the equatorial circle, and is evidently a "great circle" of the sphere. This corresponds to the Equator of the earth.

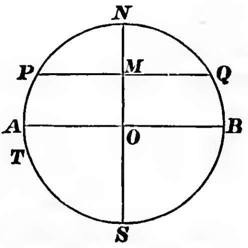


Fig. 11.—Meridians and Parallels.

Again, the point P will travel round to Q and back again to P, keeping always at the same distance PM from M, then it will also mark out a circle on the sphere; but it will be a smaller one, for PM will be less than AO. Such a circle as this is a "small

circle" of the sphere, and it corresponds to a parallel of latitude on the earth. We can see too that the nearer P is to N the smaller becomes PM, and therefore the smaller is the circle. Hence we see that if any plane cuts a sphere without passing through the centre the section with it is a "small circle," and the farther the cutting plane is from the centre the smaller does this circle become.

Meridians.—If P were the position of Greenwich Observatory, NPAS would be the "Meridian" of Greenwich—that is, it would be the line on the earth's surface which would have the same mid-day as Greenwich; and the reason for this is that at mid-day the sun is directly overhead at some point in this line. Call this point T, then OT produced will go to the sun; the sun must lie in the plane of the paper—that is, the sun will appear at its highest, or in other words, it will be mid-day, simultaneously at every point in that meridian.

Longitude.—Now let us revolve our semicircle part of the way, we will say a fourth of the complete circuit for forming the sphere. It will now have travelled through a fourth of 360°—that is, 90°—and its position will be at right angles to the page. Supposing the position of the original meridian to be that of Greenwich or 0°, if we have made our half circle revolve opposite to the direction of the sun or towards the east, the new one will be the meridian 90° E.; it will nearly pass through Calcutta. Had we made the sphere revolve in the opposite direction—that is,

to the west, we should have got the meridian 90° W., or the meridian passing through New Orleans. In the same way we may name all other meridians according to the divergence of our semicircle from its original position through Greenwich up to 180° E. and 180° W., which would be the same position, or the line NBS.

We thus get a fairly simple idea of the degrees of longitude, for when we say that the longitude of a place is 30° E. we mean that it lies somewhere in the meridian 30° E. from Greenwich.

Latitude.—To see where upon that meridian it lies we must consider the small circles. Referring to our figure (Fig. 11), since AN and AS are quarters of a circle or right angles, they would each, if the circle were graduated, contain 90°, and the circles made by all the graduations would be in planes parallel to the equatorial plane and to one another; and any point on the earth's surface would lie on some such circle, if not on the circles through the degree graduations, on some intermediate circle. We can describe such circles by naming them from the number of degrees, or degrees, minutes, and seconds they are to the north or south of the Equator.

Taking the meridian 30° E., if we divided up the northern half of it into its 90°, we should find St. Petersburg upon the sixtieth division; then we say that the latitude of St. Petersburg is 60° N. and longitude 30° E.

We have then by the use of latitudes and longi-

tudes a convenient way of fixing the position of any point on the surface of the earth.

Shortest Line on a Sphere.—When there are two points on a sphere, and a "great circle" and "small circle" of the sphere pass through them both, the part between them of the small circle will be a greater part of the whole small circle than the line which is part of the "great circle" is of the whole "great circle." The part of the "small circle" is more curved than the part of the "great" one. Now, of all lines joining two points the straight line is the shortest, and of curved ones that which is less curved than another is clearly shorter than it; it follows that the part of the great circle between our two points is less than the part of the small one between them. Hence the shortest line that can be drawn on the surface of a sphere between two points is the part of the great circle passing through the two points.

Spherical Triangles.—Now, suppose we have three points on a sphere, and join them by arcs of great circles, the resulting figure will be a spherical triangle; and if the sphere were the earth this triangle would clearly be the triangle the surveyor would have measured, and not a plane triangle as we have hitherto assumed. In fact, he may so take it without any error that can be appreciated, unless the triangles are large, but when they are large the difference must be allowed for.

Allowance for Sphericity.—Let A, B, C (Fig. 12)

be three points on a sphere representing the three stations of a survey. At each of them there will be a conspicuous mark raised above it, such as a barrel or disc at the top of a flagstaff, visible from each of the other stations. These are shown on the illustration as *a*, *b*, *c*. At A the observer looking at *b* and *c* observes the angle between them. Now this angle is the spherical angle BAC, because the lines

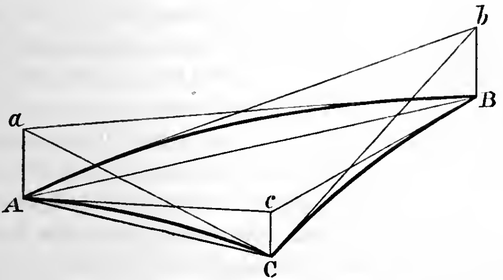


Fig. 12.—Allowance for Sphericity in Triangulation.

A*b*, A*c* are in the same direction as the first part of the curves from A; but the angle formed by straight lines drawn from A to B and A to C will be a rather smaller angle. Hence, when the spherical angles have been observed at A, B, and C, the sum of them will be a little more than the three angles of the plane triangle ABC. Now, these three angles make up two right angles; if we take two right angles from the sum of the observed angles we shall find this quantity, which is called the *spherical excess*.

The celebrated French mathematician Legendre has shown that in such triangles as we meet with in surveying, if we take from each of the spherical angles one-third of the spherical excess, and consider the curved sides of the spherical triangle as straight, we shall be able to determine the lengths of the unknown sides quite accurately by the simple methods used for a plane triangle with three such angles as we have obtained.

As an example, we will suppose that the angle at A is observed to be 60° 30′, the angle at B 62° 18′ 30″, and that at C 57° 12′ 15″; these added together are 180° 0′ 45″, then the spherical excess is 45″; taking one-third of this, or 15″, from each of the angles we have the three angles 60° 29′ 45″, 62° 18′ 15″, and 57° 12′. If in our previous surveying we have determined the length of the curved line AB which lies between the first two angles, we find the lengths of AC and BC by finding the corresponding sides of the plane triangle having a side as long as AB with angles 60° 29′ 45″ and 62° 18′ 15″ at its ends. This then gives us the practical way of allowing for the spherical form of the earth.

When accurate surveys have been made of countries, we still must find, before we can join these on together, some way of determining the relative positions of places in the different surveys. To do this, the latitudes and longitudes of several places in each country are ascertained, parallels of latitude

and meridians of longitude are drawn, and the exact position of the country on the globe of the earth is thus fixed. We will therefore now consider how this is done.

Time at Different Places.—Since the earth revolves on its axis in a day, each meridian does the same; hence the meridian NAS (see Fig. 11, p. 35) in 6 hours will be standing up at right angles to the page, in 12 hours in the position NBS, in 18 hours again at right angles to the page but standing downwards, in 24 hours again in the position NAS which we have taken to be that which it has at mid-day. Since it has thus in 24 hours moved round through 360° of longitude, it will move through 1° in 24 hours divided by 360, or 4 minutes.

Further, when NAS or the meridian of Greenwich has passed one degree upwards—that is, eastwards from its position in the figure—its original place will be taken by the meridian 1° W., whose time will now be mid-day—that is, its mid-day is 4 minutes *after* that of the meridian of Greenwich; and in the same way the meridian 1° E. will have passed through the position NAS four minutes before that of Greenwich, and so for any other meridians.

The longitude of Paris is $2\frac{1}{3}$ E., then its time is $2\frac{1}{3} \times 4$, or $9\frac{1}{3}$ minutes faster than that of Greenwich; or if it were 1 h. 40 m. at Greenwich, it would be 1 h. 30 m. 40 s. at Paris.

Again, supposing we found ourselves at such a place as Khartoum, whose longitude we did not

know, if we were able to observe when it was exactly noon, and if we found from a watch which kept accurate time and had been set right by Greenwich time before we started on our expedition, that the time by it was 2 h. 9 m.; then, since 2h. 9 m. = 129 m., we should know that we were on the meridian found by dividing 129 by 4, or that the longitude was $32\frac{1}{4}$ E.

Longitudes determined by Time.—To make use of this method it will be necessary for us not only to have such a watch (which is quite possible since the chronometer invented by Harrison in 1761 has been brought to wonderful perfection), but to be able to find exact mid-day at our position. This is a difficult matter; and therefore, if possible, we should adopt some other plan. All that we require is to ascertain the difference of time between Greenwich and where we are.

At the Greenwich Observatory the Astronomer-Royal, with his assistants, is constantly engaged in determining the exact times at which events in the heavens will be visible at the Observatory; for instance, when the moons of Jupiter will disappear behind the planet, or when particular stars will disappear behind our moon, also when and where all the most conspicuous stars will cross the meridian line of Greenwich.

Nautical Almanac.—These are published in the *Nautical Almanac*, a work of great value to sailors and explorers; indeed, a navigator would as

soon start on a voyage without his compass as without this and his chronometers.

We can make use of it to determine the longitude very simply, for such an event as one of Jupiter's moons becoming *occulted*—that is, disappearing behind the planet—will be visible from every point on the earth's surface, where it can be seen at all, at the same instant. At our position with a telescope we watch one of these moons which is near the edge of Jupiter, and an assistant watches the chronometer; we tell him the instant the moon disappears and he notices the exact time. Suppose he reads it as 9 h. 13 m. 15 s., we now turn to our *Nautical Almanac* and find that the occultation was due at Greenwich at 11 h. 22 m. 15 s.; the difference between the times is therefore as before 2 h. 9 m., and the longitude 32¼ E.

Determining Latitudes.—If we did not know Greenwich time—that is, if we had no chronometer—we should be driven to other methods; but as they are rather difficult to understand, we must be satisfied by stating that there are others which give results even less liable to error than that we have described. They will depend on our knowing the latitude of our position, which we will now show how to find.

Every one has noticed that the sun gradually rises from the horizon in the east, mounts the sky to its highest point, and then descends again to the west. When it reaches its highest point it is on the meridian of the observer, and its height above the

horizon at that moment is called its *meridianal altitude.* Now, if the observer measured this altitude on the 24th June in any year, he would find it greater than on any other day, and least on the 24th of December; if he added these two altitudes and divided by two, he would obtain the angle between his position and the pole, measured in angles on the meridian; and taking this quantity from 90°, he would have the latitude of his position.

There is one correction, however, which he would have to make—he would have to allow for having made his observations from a point on the earth's surface and not at its centre; this is called *allowing for parallax*—his *Nautical Almanac* would tell him how much to allow.

There are numerous other ways of determining latitude, much more convenient than the above, as they do not require the observations to be made at an interval of six months. As an example, the method by observing *circumpolar stars*, as they are called, may be given.

These stars are those near the pole which do not sink below the horizon in the twenty-four hours. If we observe when they have the greatest and when the least altitude above the horizon, add the results, and divide by two, we again obtain the distance of the pole from the horizon and hence the latitude.

Sextant.—The observations required for these methods can be made by Hadley's mirror sextant, which was invented in 1731 (Fig. 13). It consists of an arc

of a circle AB joined by two limbs to the centre E; there is another movable limb F revolving exactly round the same centre E, and ending in a vernier G, which enables us to divide up the graduations of the arc AB, so that we can measure down to 10″ of angle. At E, and fixed to the limb F, is a mirror N; whilst on the limb C is another mirror KL, the upper part of which is silvered and the lower part not. A small telescope is fixed to the limb D opposite to KL. The telescope is directed to the line between the silvered and unsilvered part of KL, and thence on to some distant object.

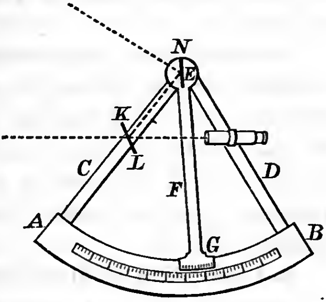


Fig. 13.—The Sextant.

If F is brought round to a certain point between A and B, there will be two images of the distant object visible by the telescope, one from the direct view through the unsilvered glass at L, the other reflected from N to K, and so to the eye from the mirror at K. When we see these two images coinciding we look at the index on the vernier, which now should point to the O of the graduations on AB. Now let the limb F be moved towards A until a second distant object, whose angular distance from the

first object is required, is reflected by the two mirrors and visible in the telescope at the same time as the first object; and read the angle marked on AB by the help of the vernier. This angle is the angle required.

If we are at sea, we can determine the altitude of a star or the sun by observing the angle between it and the visible horizon, and making an allowance for the difference between the visible and rational horizon—which difference is calculated for us in a table given in the *Nautical Almanac*—we find the altitude required.

Rational and Visible Horizon.—This will be a convenient place to explain the difference between these two horizons. A plane touching the earth's surface at the position we are in would extend out in every direction, and is called the *rational horizon;* but if we are standing on a height above the sea we should see a space of water surrounding us and extending in all directions, but bounded by a circle where the water meets the sky line; now this circle forms the *visible horizon*, and it lies beneath the rational horizon. The size of the angle between the two depends on the height we are above the sea.

Artificial Horizon.—The sextant enables us, however, to observe the altitude when we are on land, and when we cannot see the visible horizon, by the use of an *artificial horizon*, which is simply a little mercury at the bottom of a small box which is closed in by glass.

Supposing this box is placed on the ground in front of us and towards the star, the surface of the mercury will form a perfectly horizontal mirror, and since a ray of light is reflected at exactly the same angle as the angle at which it reached the mirror, if we see the star reflected from the mercury, it will look just as much below the horizon as the direct view of the star is above it; then the angle between the reflected image of the star and the direct is double the altitude.

The illustration (Fig. 14) shows this. A is the eye of the observer, AS the direction of the star, BS′ the direction of the star from the mercury at B, and ABS″ the apparent direction of the star when reflected. To determine the elevation of a star we therefore observe the angle between the direct and reflected image of it by the sextant, and half this angle is the angle we wish to find.

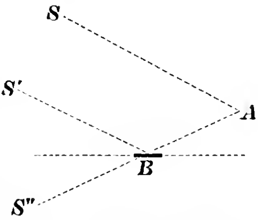


Fig. 14.—Use of the Artificial Horizon.

Variations of Level.—There is a point we have not yet considered in any of the kinds of survey we have described, although in each of them it needs attention; and that is the way to observe inequalities in the ground. The methods to be used may be arranged as three—the *barometric*, the *geometrical*, and the *trigonometrical*.

1. Barometric—(*a*) *Measured by Barometer.*—The barometer measures the pressure of the column of air resting on a surface of mercury in the *mercurial*, or of thin metal in the *aneroid, barometer*. Now, the higher we rise from the sea-level the shorter becomes this column, and therefore the less becomes the pressure; hence we have a means at once of determining the height of a hill. The calculation cannot be entered into here, but to give some notion of it we may observe, that for low elevations a rise of 91 feet will cause a fall in the column of mercury of one-tenth of an inch. The instrument, however, would be provided with a scale enabling us to determine the height.

The aneroid is most suited for explorers, as it is easily portable, and shows clearly slight variations in the height; but it requires much care and is liable to go wrong like a watch. The explorer, however, does not expect exact results, and his observations may be near enough for his purpose.

(*b*) *Measured by Boiling-point.*—Another method still used sometimes when no barometer is at hand, and which, before the invention of the aneroid, was much employed, depends on the same principle. The temperature at which water boils depends on the pressure of the air on its surface. If water is boiled on a hill-top, and its temperature is taken by a thermometer, the air-pressure can be ascertained, and hence the height can be calculated. At the sea-level, water boils at a temperature of 212°, and at a height of 510 feet at 1° less; at 2500 feet elevation the

difference for a degree is 520 feet; at 5000 feet it is 530; whilst at 18,000 feet, in the Himalaya, water boils at 180°. The rule used to give an approximate result for moderate heights is, take from 212 the number of degrees at which water is found to boil, multiply the difference by 530, and the result is the height in feet.

2. Geometrical—*Measured by Spirit-level.*—The geometrical method is to place the instrument known as the *spirit-level* at a convenient spot on or near the line the heights of the various points in which are to be found. This instrument consists of a telescope whose direction is carefully adjusted by means of spirit-levels so as to be exactly parallel to the horizontal plane. At the various points along the line whose heights the surveyor wishes to determine, an assistant holds an upright staff 14 feet long, having painted on it a scale of feet and tenths of a foot measured from the ground. He looks along his telescope at this staff and notes the various heights which are visible at the cross spider lines in his telescope. Now, the distances apart of his observations show the difference of height of the different points.

Suppose the line AG (Fig. 15) represents part of the line in which heights are to be found. The observer places his spirit-level at Y, and observes that the number he sees at G is 1 foot, at F 11 feet, at E 12·7 feet. If he knew, to start with, that the height of G was 100 feet, he now knows that that of F is 11 feet less 1 foot or 10 feet lower—that is, its height

is 90 feet; if his telescope is 5 feet from the ground, Y must be 96 feet high. At E, which is 12·7 feet – 1 foot less than G, the height must be 88·3 feet. Now he moves his instrument to X, and as before observes the staff when placed at E, D, C, B, and A,

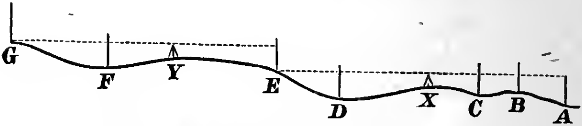


Fig. 15.—Measurement of Heights by Spirit-level.

and then in the same manner determines the height of each. Our sketch is not supposed to be drawn to scale. In favourable weather it is possible to observe the marks on the staff even at a distance of 400 yards, so that we might imagine AX or GY to be such a distance as that.

A somewhat similar method is used when the slope is so steep as to render "levelling" very slow

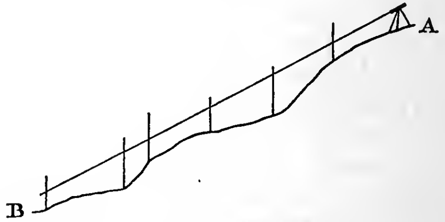


Fig. 16.—Levelling a Steep Slope.

and difficult. If AB (Fig. 16) is the slope, a theodolite placed at A is depressed so as to look

along the general slope towards B; staves are held up at various points along the line of sight, the heights are read off, and the distances between the staves are measured. If the height of B is known, that of A can be calculated from the general slope of the line and the height of each point where a staff cuts this line of slope; then, if the observed height to the ground is subtracted, the height of the ground at each of the staves is found. There is another way something like this which will be given as a useful one for rough military work (see p. 55).

3. Trigonometrical—*Measured by Theodolite.*—The third or trigonometrical method of determining heights is in many cases the only one available. In any geography book we shall find the heights of Mount Everest, Kanchinjinga, Dhaulagiri, and many other peaks in the Himalaya given to within a foot, and yet, as far as we know, no foot of man has ever climbed the rocks or trodden the snow about their tops, nor come within thousands of feet of them; no aneroid or spirit-level has been used near them; then we ask ourselves, How have we arrived at this knowledge? The answer is, by the application of trigonometry to expound the meaning of the observations made by the most accurate use of the theodolite and similar instruments.

One example of a simple case will be enough. At A (Fig. 17) we see a distant mountain-top X, and between us and it there extends a level plane as far as B. With the utmost care we measure the angle XAB,

then advance to B, in the direct line towards X, measuring the distance AB with every possible precaution against error; at B we observe the angle XBY, and we have now enough facts to determine the height of X. Since we know the angle XBY, we know XBA, for the two make up two right angles. Then in the triangle XBA, since we know two angles and the side AB, we can calculate the side BX. In the triangle BXY we know that XYB is a right angle, XBY has been observed, and XB has been calculated, then we can calculate BY and XY—that is, we know the exact position of Y and the height of X above the plain.

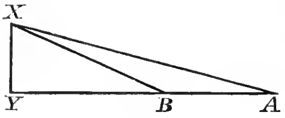


Fig. 17.

In practice it is seldom as simple as this, for we shall have to make allowance for AY not being a straight line but a curved one in consequence of the earth being a sphere. Again, we shall practically hardly ever be able to secure a level plane with a horizontal line extending as from A to B, and so we shall be obliged to use more observations and more calculations, but they will really depend on the same principles.

There is a striking example of the wonderful exactness with which this "levelling," as it is called, can be executed. The Italian Government had determined to cut a tunnel under the Alps, and the work was undertaken and carried out by Italian engineers. Though called the Mont Cenis Tunnel it is really

under Mont Frejus, a mountain 10,000 feet high, and rising so steeply at both ends of the tunnel that half a mile from those ends there is a height of 1500 feet above the proposed line; besides this, one end was very much higher than the other. The length of the tunnel is $7\frac{3}{5}$ miles.

In ordinary tunnel-making, shafts or pits are sunk at intervals, and the miners, working from the bottoms of these as well as from the ends, have then only short distances of rock to pierce before they cut their way through; but the height of the mountain and the steepness of its sides made any such plan impossible. It was necessary to start from the two ends and bore directly into the bowels of the mountain, depending on the accuracy of the calculations that the two tunnels thus made should run into one another. This was triumphantly done; the two lines of boring over three miles long met almost centre to centre.

To give some notion of the accuracy here required, suppose we had a large cheese, and from a point seven inches up one side and two inches up the opposite one, two long and very fine needles were to be thrust in, and that it was necessary for them to meet exactly point to point in the middle, and that the failure to meet would cost very many thousands of pounds, and would ruin the credit of the operators. Would any of us undertake such an experiment? Would any one succeed?

But even this illustration does not fully express

the difficulty. The mountain is a rugged irregular mass connected with a vast chain stretching for many miles. The exact comparative heights and relative positions of the ends had to be calculated by levelling and the other most delicate methods of surveying, and then, when the directions of the borings had been determined, very ingenious but simple guides were devised to keep the miners working in the true line.

Contour Lines.—The heights of particular points can thus be found, and the undulations along a line can be measured and registered, but it is necessary to have some way of expressing these variations of altitude on paper. The plan now made use of is by Contour Lines. These are lines drawn at intervals on a map, each line passing through all points on that map which stand at the same level above some fixed height, which is called the *datum-level.*

On extensive surveys this datum-level is usually what is called the level of the sea; and when the height of a mountain is stated to be 1300 feet, the meaning is that the summit stands so many feet above the sea. Of course there may be a good deal of difference between high water and low water; but it is an understood thing that the sea-level is the average height of the sea, or, as it is called, *mean sea-level.* For practical purposes this level is uniform throughout the world. It was supposed before the Suez Canal was cut that there was a

difference of level between the Mediterranean and the Red Sea, but this was found not to be so; and there seems a strong probability that the level of the sea on the opposite sides of the Isthmus of Panama is the same.

In military maps the contouring is very important, for on the undulations of the ground depend to a great extent the value of positions for an army. A good map will enable an officer to move his men from one position to another without coming under fire or within sight of an enemy who may be quite close to him, and to place them where the ground to their front and flanks is exposed to their own view and fire. In the roughest military surveys, then, this point has to be attended to.

Determining Contours roughly. — Starting from the top of a hill whose sides he wishes to contour, the military surveyor will observe the general slope and direction along one of the spurs of the hill, which will be a line of least slope from the top. This slope will be measured by some form of *clinometer.* Watkin's mirror clinometer is commonly used.

Any one can construct for himself a simple instrument, by making a protractor in cardboard with a semicircle that has been graduated to the edge of the cardboard. He will place the 0 at the graduation corresponding to the ordinary 90° of a protractor, and fill in his numbers to the right and left of this. At the centre of the semicircle he will insert a thread having a plummet at the other end,

which will swing freely as a pendulum. To use this instrument he will look along the upper edge of his protractor to a mark below him at the farthest point where the slope is uniform, then when the plummet-line is steady observe the angle registered. This angle is the angle of slope.

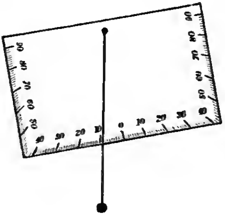


Fig 18.—Simple form of Clinometer.

On military protractors there is given a scale showing how many yards the observer must advance for each angle of slope to reach a point 20 feet below his original position. Suppose the angle of slope was 10°, the corresponding number of yards will be 38. He then paces down this number of yards, and knows that he is 20 feet below his original position; and if his contour lines are to be placed at vertical intervals of 20 feet, he will look at the slopes of the hill on each side of him, and judging by the eye the form of the line at his own level, draw it on the paper. He will then go down another 20 feet, and so on till he reaches the bottom of the hill. Mounting the hill again he will descend another spur, and all the spurs in succession, and so be able to draw a plan of the contour lines.

Accurate Method of Contouring.—In exact surveys the process is similar. Supposing as before that the contour lines are to be 20 feet apart, the sur-

veyor will level along a line of least slope with his spirit-level or theodolite. When he has ascertained the point 20 feet below the highest contour line, if using the theodolite, he will level his plates and telescope; then an assistant will walk along the slope of the hill and hold up a staff at points about on a level with the instrument. The surveyor revolves his telescope till he observes the staff. If the height observed is the same as the height of the instrument from the ground, the staff is on the contour line, if not, the assistant must be directed to move up or down the hill till it is. One point on the contour line having been ascertained, and a staff placed there to mark it, the assistant proceeds to a farther point, and so along the contour line until a succession of points on it, visible from the telescope, have been marked.

When the assistant has reached another spur, and marked the point on it, the surveyor takes the theodolite to this new position and continues the observation of the contour round the hill till he comes back to his original position. He then descends another 20 feet and observes the contour there, and continues the same process until the whole hill is done. The contour lines will be completed by determining the lines connecting the marked points on each by the plane table, or by traversing with chain and compass.

III.—GLOBES

Having completed the surveys of countries, it remains to express them in such a form as to be available for use. Now the simplest, most accurate, and for many purposes the most useful form is a globe. Doubtless, if we could have maps drawn on portions of a globe, instead of on flat sheets of paper, they would convey to the eye a much better idea of the real shape of a country and the relative positions of places, but they would be very expensive, and not handy to use, even if there were a convenient way of making them. But when we come to the world as a whole, without doubt globes are by far the best mode of representation that has been devised.

Ancient and Curious Globes.—The most ancient globes we have were made in metal, and were celestial ones—that is, they showed the position of the stars in the apparent sphere of the sky. There is a copper one of the eleventh century in the National Library at Paris; and the Emperor Frederick II had a celestial globe made of gold, with pearls for the stars.

The earliest terrestrial globe in existence is one

21 inches in diameter, made by Martin Behain of Nuremberg in 1492; it is made of pasteboard covered with parchment, and it shows the world according to Ptolemy's calculations. It has only one meridian, that of Madeira, marked upon it, and the Equator, tropics, and polar circles.

The Laon globe, made in the next year, has the meridian lines at 15° apart marked on it; it is engraved on copper. So is the little globe found in Paris, and now in the Lenox Library, which was probably made about 1506. There is in the Library at Nuremberg a very interesting one by Schöner. It shows the discoveries of Cabot and Columbus; but where their discoveries end he places sea, and so breaks up the Americas into islands.

It is indeed very curious to trace in the early globes the gradual growth of knowledge. At Nancy there is a silver globe in which America is joined to Asia; but the brass Ecuy globe made a few years later separates them. In 1541 Mercator published his celebrated globes, which accurately gave all information that was then possessed. In 1592 an English geographer, Molineux, produced globes in which the limits of the voyages of Frobisher and the discoveries of Drake were marked. One of these can be seen now in the Middle Temple Library.

These are some of the most celebrated old globes, but many later ones are also curious. In Paris there is a pair of 12-foot globes, made by the astronomer Coronelli, and presented by Cardinal d'Estrée to Louis

XIV. They are constructed of wood covered with cloth. In the Mazarin Library there is a copper globe 8 feet in diameter.

Perhaps the most interesting is the Gottorp globe in St. Petersburg, which is 11 feet in diameter; the exterior is terrestrial, the interior, which can be entered from beneath, is celestial. It was given by Frederick IV of Denmark to Peter the Great.

At one time Leicester Square, London, was occupied by a large building, the interior of which formed a globe with a diameter of 60 feet. This was constructed by a man of the name of Wyld; and as all parents and schoolmasters considered it their duty to show it to children, the place had many visitors. It was supposed to combine instruction with amusement; but there was little of the latter, and there could not be much to be learnt from it, for looking at the earth turned, as it were, inside out, was to most visitors rather confusing. This great globe was not the largest ever made, for Langlois, a Frenchman, had previously, in 1825, made one with a diameter of 120 feet.

Manufacture.—Making an ordinary school or library globe requires much skill and care. The mould on which it is made is a hollow wooden or metal sphere with an axis ending in poles. This mould has about a quarter of an inch less diameter than the globe to be constructed if that globe is small, with more difference if it is large. It is carefully greased, then strips of damp white paper are spread all over

it, and a coat of paste applied to them; on these again are carefully arranged strips of brown paper soaked in paste till they are quite soft, and on the brown, white, and so with alternate layers till a coat about one-sixteenth of an inch is formed, when it is allowed to dry completely. This, although about the same thickness all over, forms but a rough sphere. It is now cut in two along the Equator and removed from the mould, a wooden axis surmounted by poles is provided, and the two half spheres, after being fitted on to them, are glued together with great care. It is next covered with a composition made of whiting, boiled oil, and glue, until it is fully the size required. Its surface is planed by a metal semicircle, whose ends fit on to the poles, and this is worked round and round the sphere until the surface is quite smooth and true.

When it is hard and dry, the equatorial circle and circles of latitude are carefully marked on it, and then the meridians of longitude; for ordinary globes these will be 20 degrees apart.

Now the maps are applied; they consist of separate strips or gores much in the shape of a willow leaf, each one having engraved on it a map of a strip of the earth between 20° of longitude, but the ends are cut off, so as to allow a small circle at each pole to be pasted on separately. Before beginning to paste on the gores, they are carefully cut out, damped, and placed in a pile over one another in the order in which they will follow one another on the globe. The maker now

pastes one gore on, carefully fitting its edges to the meridians on the globe and the Equator and parallels of latitude on his slip in continuation of the corresponding lines on the globe. Then adjacent to it he pastes on the next gore, and so on till the globe is covered. The next process is to size the whole, and colour it, then lastly to brush it over with several coats of spirit varnish.

The Stand.—The model of the earth is now complete; but it has to be mounted. The two pins which form the poles are fitted into a brass circular ring, whose inner edge is just large enough to allow the globe to rotate freely. This constitutes a meridian, and is called the *brass meridian;* it is graduated on one of its semicircles from the Equator up to the poles and on the other from the poles to the Equator. As the globe is turned round it successively stands exactly over each of the meridians on the globe.

The *horizon* is a broad wooden ring, with its inner circle rather smaller than the outside circle of the brazen ring, with two grooves on opposite sides of it for the brazen ring to work in. Its flat upper side will be divided into twelve parts, showing the months and the signs of the zodiac—that is, the signs for the twelve constellations or groups of stars across which the sun appears to move during the year,—and its inner edge is graduated into 360 degrees.

There is usually also a small brass circle at the North Pole divided into 24 parts, to represent the 24 hours of the day; this circle is movable, or, if

fixed, has a movable index. On the globe itself there is drawn the ecliptic circle.

Uses.—The uses of a globe are numerous. The first use, and by far the greatest, is to convey to the mind a distinct notion of the comparative sizes of countries and the relative positions of places. No map can do this satisfactorily if the places are far apart, but it is easy with a globe.

As examples of this use, turn the brass meridian of a globe round till England is at the highest point, and observe how well situated our country is in the midst of the masses of land in the world, with its water-way to each civilised and productive part of the earth, whilst the opposite hemisphere is mostly a vast waste of waters,—the Pacific with its small scattered islands and no large masses of land but Australia and the south of South America, and the Antarctic Ocean with its unknown lands about the South Pole. Again, turn the globe until the Equator on it coincides with the horizon, and observe how large a proportion of the lands of the earth lie in the northern hemisphere, and how little in the southern.

But we must remember that it is not the observation of a few points like these so much as the glances at a globe from time to time which fix the relationships of places in the mind. For instance, we all know where to look for the antipodes to England, but if we are not accustomed to study a globe, we cannot at once see in our mind's eye the antipodes to other places. Again, a globe shows us at a glance

all the places on the same latitude—a matter in which a superficial knowledge of maps tends rather to mislead us.

Distances and Directions.—The next point to notice is how to determine by the globe the distances apart of places. A quadrant of thin brass, or even of paper, to fit the globe, and graduated into degrees and half degrees, is very useful for this. Place the quadrant between the two places so that the 0° of the graduations is at one place, and observe the angle at the second; this gives the angle of a great circle between the two; then, remembering that 1° of a great circle is very nearly 69 miles, we can calculate the required distance.

This can be done equally well with a pair of dividers. Measure the distance by them between the places, and then determine the angle between them by measuring the same distance on the Equator, taking one of them at the zero meridian, then the calculation is the same as before. A piece of string will do as a rough substitute for the dividers.

The following will be an interesting illustration of the use of our quadrant. Turn the globe so that England and Japan are visible at the same time, and remembering that in the old days a ship sailing from the former to the latter must either pass round South America, or round the south of Africa and Asia, observe the direct route with the quadrant. Hardly any one, if unaccustomed to globes, could judge from looking at maps what the line would be. We shall

find that it runs past Spitzbergen, not very far from the pole, and on the same side of it as Asia; the distance is about 86° of a meridian, or about 5900 miles. The route by the Cape of Good Hope is 240° of the meridian, or about 16,600 miles; that by Cape Horn 275°, that is about 19,000 miles.

When we consider this we cease to wonder at the old navigators having been so anxious to discover a north-west or north-east passage to China and Japan. Even now with the Suez Canal route the journey is 12,800 miles, or considerably more than double the direct line.

Supposing we wished to determine the longest line between points in Asia. This would be from Aden to East Cape on Behring Straits. If, turning to a map of Asia, we drew a line between the two points, it would pass through the south of the Persian Gulf, skirt the Thian Shan and Altai Mountains, and pass half way between the Arctic Ocean and the Sea of Okotsk, and it would have a length, calculated by the map scale, of about 6900 miles. Now, measuring on the globe, we find that the real distance differs only 200 miles from this, as it is 6700, but the direction is quite changed. It would cross the north of the Persian Gulf and the Sea of Aral, pass near Tobolsk, and skirt the shore of the Arctic Ocean opposite the Liakhov Islands.

Rhumb-line and Great Circle Sailing.—These examples lead us naturally to others which are of great practical value to navigators. The old-fashioned

and unscientific sailor steers his course on what are called *rhumb-lines.* The port he is making for lies perhaps to the S.S.W. of that from which he starts; he will then keep his course always S.S.W. until he arrives. The consequence is that he very nearly travels on a certain small circle of the globe; but his direct and shortest route would be on the great circle passing through the two ports. Steering along this is called "Great Circle Sailing."

In these days of rivalry in speed across the Atlantic it will be interesting to notice what the difference between the two courses will be. A vessel travelling from the Land's End on the parallel 50 N. to St. John's, Newfoundland, on the parallel $47\frac{1}{2}$ N., would on the rhumb-line pursue a course very slightly south of west, and would travel from the meridian $5\frac{3}{4}$ W. to 53 W., or through $47\frac{1}{4}°$ at the average latitude of $48\frac{3}{4}$ N. The length of a degree of longitude on that latitude is 45·47 miles; then the journey would be 2146 miles. On the great circle course, as measured on the globe, she would sail considerably to the north of west; with longitude 20 W. she would be in latitude $51\frac{1}{2}$ N., and would not again cross the parallel 50 N. until she had nearly reached 40 W. She would accomplish the distance in 2110 miles, and would thus have saved 36 miles.

We will take another and much more striking example. A ship sailing from Cape Town (35 S. $18\frac{1}{2}$ E.) to Melbourne ($37\frac{3}{4}$ S. 145 E.) on the rhumb-line travels a little south of east for 7000

miles; but on the great circle she would start much more to the south, would reach the 80° meridian at 60° S., and would accomplish the distance in 6350 miles, thus saving 650 miles.

It is evident that the gain is proportionally much greater when the places are far apart, and also when they are not near the Equator. In the latter case the rhumb-line is so nearly a great circle that the difference is hardly appreciable.

To enable the student to work out similar calculations for himself, there is given in an Appendix a Table of the lengths of a degree of longitude at the different latitudes.

Our grandparents used to be taught what was called the "Use of the Globes." This consisted of learning how to shift the globe into various positions, and thus to ascertain roughly answers to a number of scientific questions such as—Given the time at one place, what is that at another? What is the duration of twilight at some required place? What is the time of sunrise, and the length of the day at some place at a given date? If the answers had been anything but very rough they might have been of some practical value, but they were not, and as the principles on which they were worked were not explained they had no great value as means of education, and are now therefore no longer taught.

To Determine Latitude and Longitude.—We will take a simple specimen of the use of globes, which may be found sometimes of use. Supposing

we wished to find the latitude and longitude of a spot on the earth, we should turn the globe round till the brass meridian was exactly over the place; we should observe the degrees at it from the Equator as marked on the meridian, this would give us the latitude, and the degrees marked on the Equator of the globe where the brass meridian cuts it would give the longitude. By this method with a good library globe we may obtain the latitude very fairly, and also the longitude, if the place is not far from the Equator; but if it is near one of the poles we can only judge it very roughly.

Day and Night.—But although an elaborate study of such problems is not of use, we gain a very clear idea of many questions relating to mathematical and astronomical geography by examining a globe. Thus if we place the globe with the North Pole above so that $23\frac{1}{2}°$ N. latitude on the brass meridian is opposite the wooden horizon, its plane becomes the plane of the ecliptic; then if we stand at a considerable distance from the globe with our eye in the plane, we look at nearly the whole portion of the globe illuminated at the same time by the sun. We should see quite the whole if we could move far enough away. If our eye is opposite the edge of the meridian with the North Pole leaning towards us, the position of the globe is that of the earth at the midsummer of the northern hemisphere. We are able to see the North Pole and nearly the whole of the Arctic Regions. If the globe is rotated

we see the Arctic Regions the whole time, which illustrates the fact that the sun never sets at midsummer in that part of the earth; and as the South Pole and the Antarctic Regions are never within sight during the rotation of the globe, it is clear that while it is midsummer in the northern hemisphere it is winter in the southern, and that south of the Antarctic Circle the sun never rises during this part of the year.

Again, we shall observe that every point on the Tropic of Cancer will just come down to the plane of the ecliptic or wooden horizon during the rotation, hence each of these points on the earth has the sun vertically overhead at its mid-day. This explains the true meaning of the tropic.

Looking at the northern hemisphere, we see more than half of it; and therefore any point in the Temperate Zone during the rotation is longer in sight than out of sight—that is, during the summer the day is longer than the night, whilst the reverse is the case for all places in the southern hemisphere. If we move to the exactly opposite side of the globe, all these positions are reversed, and we see summer in the southern, winter in the northern hemisphere.

Now we move to a position half way between these two, and, if far enough away, we can see to each pole. When the globe is now rotated every place is as long visible as invisible, explaining the reason for day and night being equally long at the equinox.

Twilight.—The subject of twilight is very interesting, but not easy to understand, yet it may by the help of a globe be made clear. Light in passing through any transparent substance, such as the air, loses something of its brightness; the light lost is distributed, or, as it is called, diffused, in all directions; but, as we should expect, there is more of it in the immediate neighbourhood of the direction of the ray than farther off. When the sun is near the horizon, the rays of light from it pass through the air for a long way, and there is then much diffusion of light. It is considered that until the sun is 18° below the horizon a perceptible quantity of its light reaches the earth; hence in the interval between sunset and the sun reaching 18° below the horizon there is twilight, and similarly twilight for the same time before sunrise.

Travellers to the tropics always observe how suddenly it gets dark after sunset, and voyagers to high latitudes are equally struck by the length of the twilight, so that at midsummer there appears, even when they are considerably within the Temperate Zone, to be no darkness, or, at most, very little.

Let the circle in the illustration (Fig. 19) represent the earth at midsummer, with P for the north, P′ for the South Pole, and FOG for the Equator. OS is the direction of the sun from the centre of the earth, and ACB will represent the hemisphere on which the sun is shining, AB being drawn at right angles to OS. DE is a line parallel to this, having AD an arc of 18°. Then the band round the earth between AB and DE

will be the part of the earth's surface which at this time will be in twilight. Now a point on the Equator above O will, as the earth revolves on its axis, have twilight until it reaches H—that is, whilst the earth revolves through 18°, which will take 18 × 4 minutes, or 1 h. 12 m. Again, consider the point K, where

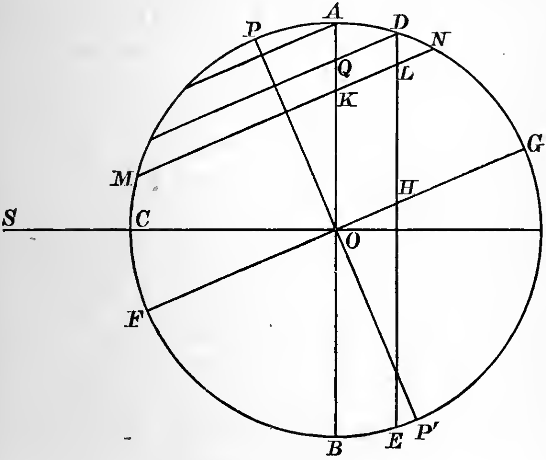


Fig. 19.—Twilight.

the sun is also just setting. It will be in twilight until it has crossed the band and reached L; but KL is a much greater portion of the whole parallel of latitude MN than OH is of FG, then K will take much longer to reach L than did O to reach H; hence twilight will last much longer. When we reach a point farther north, as at Q on the same

latitude as D, we shall have no dark night at all, for directly after passing D the twilight before sunrise of the next day will begin.

This explanation may not seem very distinct, but let us place the globe as in our previous experiment with it, and cut a few narrow slips of white blotting-paper, making each of them as long as 18° on the Equator. Wet them and place them at right angles to the visible edge of the globe with the nearest side just visible to the eye which represents the sun. Now watch these slips as they come into view when the globe is very slowly rotated. The farther end of the slip on the Equator will be first visible, and those nearer to it will become visible sooner than those on the higher latitudes. Remembering that the farther end of each of our strips was in twilight before the revolution of the globe began, we see that twilight lasts the shortest time at the Equator and longer the farther we move from it north or south. After trying the experiment, if you read again the explanation, it ought to be quite clear.

We have but given examples, the experiments that can be tried are endless, and with each fresh one knowledge and understanding of the properties and uses of the globe will grow upon the student. Wherever he has a difficulty in understanding the phenomena of mathematical geography, let him turn to the globe and see if he cannot make it out; if he can for himself so much the better, if not let him apply for help.

IV.—MAP-DRAWING

We have seen how lands are surveyed, how they are connected by latitudes and longitudes, and how they are modelled on globes; our next step will be to discuss how they can be represented by maps.

The necessity for these is obvious—globes are too cumbersome, too expensive, and would have to be of enormous size if we wished to have the details of countries expressed on them; and for small tracts of land, such as an English county or even a country of the size of Switzerland, the rotundity of the earth makes so little difference as to be practically unnoticeable.

Difficulty of Development.—It is clear that we cannot lay the surface of a globe out flat. If we were to cut a square piece out of an india-rubber ball, we could only make it lie flat by stretching the edges a good deal, and the rest of it more or less according to the distance from the middle point. Supposing two points near the edge of the square were originally a quarter of an inch apart, after the stretching they would be much farther apart, whilst two points

near the middle would remain very nearly at their original distance.

Again, if the points were near the edge, and if, when stretched out, one of them came to the corner, whilst the other was half-way along a side, the first would be much farther from the centre, whilst the second would be comparatively little farther, so that the direction of the line joining the points would be changed with respect to the centre. These are some of the difficulties which map-drawers have to meet.

Orthographic Projection.—The first notion of representing a round body on the flat would naturally be to draw it as we should see it from a distance. Take ABC (Fig. 20) to represent half the Equator as viewed from a point P, the distance of which from the Equator is the radius of the earth. If from P we draw tangents PD and PE to ABC, DE will clearly be the part of the Equator visible at P. Now divide DB into four equal parts in the points FGH, and draw PF, PG, and PH. Since these lines are the lines along which we should look to see the points, it is evident that G and H will appear nearer together than B and H, F and G still nearer together, and F and D quite close. Supposing we draw a line through B at right angles to BP, this line would represent where a tangent plane or horizon plane at B met the Equator plane.

Now the points H, G, F, and D would appear to the eye at P exactly in the same relative positions to one another wherever they were along the lines

PH, PG, PF, and PD—that is, *h*, *g*, *f*, *d* could be substituted for H, G, F, D; then the line *d*B would be a picture of the appearance of DB as seen from P.

In the same way, all points on the globe visible at P would be pictured by corresponding points on the tangent plane. We could thus have a map drawn on a flat surface representing a part of the globe;

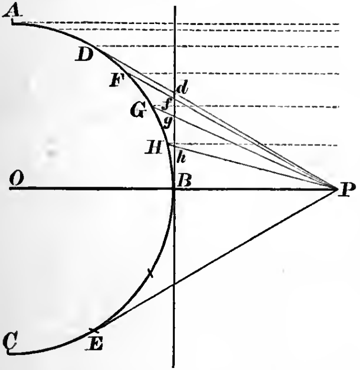


Fig. 20.—Key to the Orthographic Projection.

but it would be a very bad one, for if at the middle of our map a distance such as A*h* represented 1000 miles at the edge of our map, an equal distance would be represented by *fd*, which would be so deceiving as to make our map quite worthless.

The points *h*, *g*, *f*, *d*, and the picture of the earth on the tangent plane are called the *projections* of the points H, G, F, D, and of the globe for the point P on the tangent plane.

This phrase must be clearly understood, as the term projection is one we shall have to use constantly in describing other and better ways of representing a sphere on paper.

The strict definition of a projection is that if through every point on a given curve straight lines are drawn from a given point so as to meet a plane, the curve connecting the points on the plane is the projection for the given point of the given curve on that plane.

In map-drawing, however, we shall find that the phrase is enlarged, and that we shall call every representation on a plane of lines on a globe a projection.

Returning to our figure (Fig. 20), we can easily see that the farther we take P from B the nearer do *df*, *fg*, and *gh* become in length to *h*B, so that if we took P at such a great distance off that the lines drawn to H, G, F, etc., were practically parallel, as shown by the dotted lines, we should get a very much better map; still, there would be a great difference in scale between the middle of it and parts some way from the middle, and at the edges it would be distorted to a fatal extent. This projection is called the *orthographic projection.*

It is not of much use for ordinary maps, as we shall see there are many others much better, but it is well suited for maps of the polar regions, for the meridians become all straight lines, and the parallels of latitude are circles round the pole.

The illustration (Fig. 21) gives a network of lati-

tudes and longitudes at 30° apart for one hemisphere; the parallels of latitude are straight lines, and the meridians are generally ellipses. This shows how unsuitable it is for maps of any considerable part of

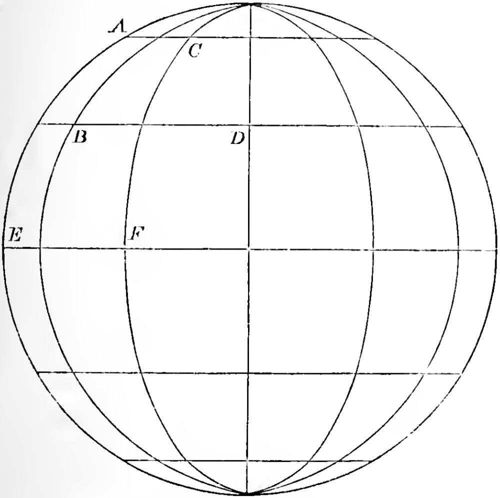


Fig. 21.—Orthographic Projection of the Globe.

the earth's surface, for the spaces AB, BC, and CD are on that surface exactly of the same size and shape as are also the spaces EB, BF, and FD.

The next projection we will describe is known as the **Gnomonic** or **Central Projection**. Here we suppose the eye placed at the centre of the globe, which may be looked upon as a transparent sphere,

and lines are drawn from this centre to each point on the globe and produced to meet the tangent plane. Then, as in the first case, the projection on this plane will be the map.

The annexed figure (Fig. 22) shows this. The

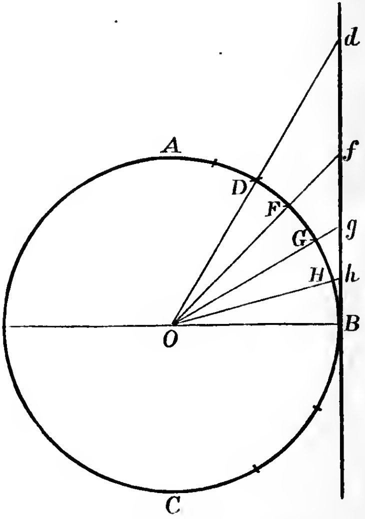


Fig. 22.—Gnomonic or Central Projection.

Equator and its points of division are the same as in Fig. 20, and B*d* is the projection of BD. We see at once that the length of *gh* is slightly greater than B*h*, and that the exaggeration keeps on increasing, so that *df* is vastly too long. Indeed, beyond D the projection becomes useless, and a hemisphere cannot

by this method be projected at all, for the line OA will never meet the tangent plane.

This projection has some advantages. For all great circles, such as the Equator and meridians, are represented by straight lines; but the small circles

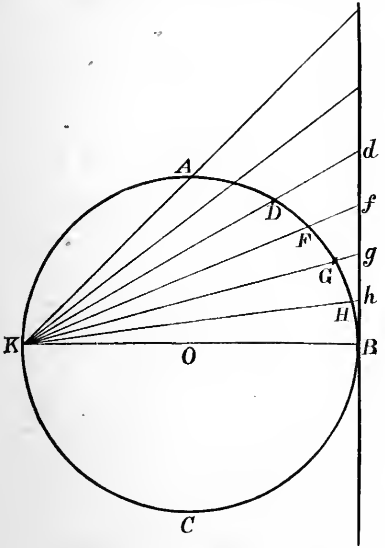


Fig. 23.—The Stereographic Projection.

are ellipses, or in certain cases other conic sections. It is used for star-maps of small portions of the heavens, but not for terrestrial maps, because of the great variation in the scale.

The Stereographic Projection (Fig. 23), however, is still much used, and by many is considered the

best of all. In it the point of projection is not the centre of the globe as in the *gnomonic*, but a point K on its surface opposite to B. We see from the diagram that although *hg*, *gf*, and *fd* still are longer than *h*B, they do not increase nearly so rapidly, and consequently spaces near the edges of a map are not so seriously too large as to spoil the map for practical purposes.

The other great advantages of this projection are, that all circles on the globe are represented by circles on the map, and lines cutting one another on the globe cut one another at the same angles on the map; and further, the distortion of parts of the map near the edges is not so great.

The last of the true projections that we shall consider is the **equidistant** or **globular projection** (Fig. 24). In this method the line BOK is produced to a point L, so that KL is half of AK. Now the distances B*h*, *hg*, *gf*, *fd*, etc., are very nearly equal, so nearly, that in map-drawing they are made equal. Again, the parallels of latitude are really arcs of ellipses, but so nearly arcs of circles that they are so drawn in our maps.

This is the projection generally used in modern maps of the world in hemispheres, and it will therefore be well to see how the construction is effected (see Fig. 25). For simplicity, we only draw the meridians and parallels at 30°, but it is quite as easy to draw them at 20° or 10° apart. First we draw a circle to represent the outline of our hemisphere, then two diameters at right angles to one

another—the horizontal one will represent the Equator, the vertical one the middle meridian. Next we divide each radius and each quadrant into three equal parts; then draw the other meridians by determining the centres of circles passing through

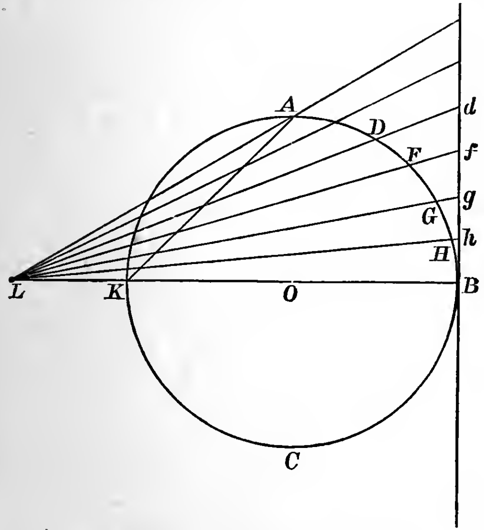


Fig. 24.—Equidistant or Globular Projection.

each pole and the points of division on the Equator; and the parallels of latitude by the circles passing through the division points on the vertical radii and the corresponding points on the quadrants. These centres could be easily determined by construction, but they can be more quickly fixed by trial, as we

know that the centres of the first set all lie in the Equator or that line produced, and the second set in the middle meridian produced.

When we compare the network thus obtained, we see how greatly superior this is to the orthographic

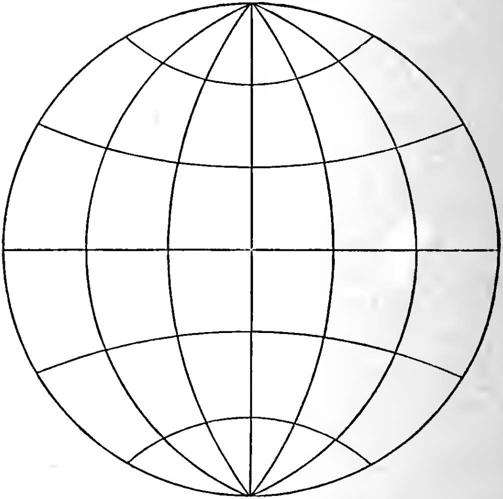


Fig. 25.—Construction of a Map of the World in Hemispheres on the Equidistant or Globular Projection.

projection given before; though there is undoubtedly a very considerable difference in the scale at the middle and edges of the map; but the meshes of the net between the same parallels are much more nearly of a shape, and therefore the maps near the edges will not be so greatly distorted.

Conical Projection.—Geographers have invented several other projections, but they possess no great advantages, and are not used in maps which the ordinary reader is likely to meet with, so that we need not trouble about them; there remain, however, two methods commonly called projections, but which should be called developments, of great value to the map-drawer.

If we twist a sheet of paper into the form of a cone, and place it on a globe, the surface of the globe touches it in a circle; and if the vertex, or highest point of the cone, were placed in the axis of the globe produced, the axis of the cone and globe would be the same line, and the circle of contact would be a parallel of latitude. By framing our cone of suitable shape, we could make this circle any parallel we might choose except the Equator.

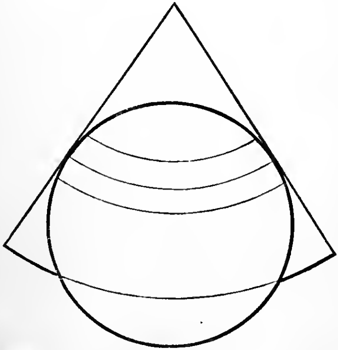


Fig. 26.—Conical Projection.

The diagram (Fig. 26) explains itself. It shows that the belt of the cone extending some distance on each side of the touching circle will all of it very nearly touch the globe. Then, if straight lines be drawn

from the centre of the globe through points on its surface within this belt to the cone, we shall have on the cone a very accurate representation of this portion of the globe.

Supposing this is done, and the paper untwisted and laid flat, we shall have a very good map of the belt. This is called a *conical development*, and is almost universally used for maps of separate countries, and sometimes even for Europe; but for the latter it is not well suited, as the belt within which a map of the continent lies is too wide. Generally the largest space of country for which it is well adapted would not stretch beyond 30° of latitude; but in the Royal Atlas European Russia is drawn on it, though that country lies between 40° N. and 75° N.

The greatest advantage which this method of construction possesses, although there are many others, is that the edges are not distorted, as each mesh between the same latitude is exactly of the same shape. Slight modifications are made use of to increase its accuracy, or make it easier to draw, the chief of which is to suppose the cone not to touch but to cut the sphere in two parallels of latitude half way between the middle and extreme parallels. Another slight modification, so slight as to be in most cases quite imperceptible, is to consider the distance apart of the parallels exactly equal.

As an example of the practical way of using this method, we will prepare a **network of latitudes and longitudes for a map of the British Isles**

(Fig. 27). We first draw a scale of miles. In our example, to bring the map into the page, the scale has been drawn at 250 miles to the inch. The limits of the map will be from 50° to 60° N., or 10° of latitude, and from 2° E. to 11° W., or 13° of longitude. Hence our middle meridian will be 5° W., and supposing we draw our parallels and meridians at 2° apart, there will be 5 parallels to be marked along the middle line AB of our map, each measuring 138 miles by our scale, and we number the points marked as 50°, 52°, 54°, 56°, 58°, and 60°. The middle parallel along this would be 55°, and the best positions for the cone to cut the sphere would be $52\frac{1}{2}$° and $57\frac{1}{2}$°; but to save trouble in calculations and drawing, we shall take it at 52° and 58°, as the difference would be quite inappreciable, and these are two meridians that we require.

The distance along the parallel of 52° between meridians 1° apart is 42·5 miles, then from this point we mark off perpendicular distances of 42·5 on each side of the meridian. At 58° the corresponding distance is 36·6, then we similarly mark these distances at that point. We have now determined the four points C, D, E, F; we join them, producing CD and EF both ways, and draw perpendiculars through each of the marked points on AB to meet them.

This gives the middle strip of our map between the meridians 4° and 6° W. It only remains to repeat this as far as is required on both sides. Generally

the most convenient way to do so is to trace this slip on a piece of tracing-paper, and then, turning

BRITISH ISLES.

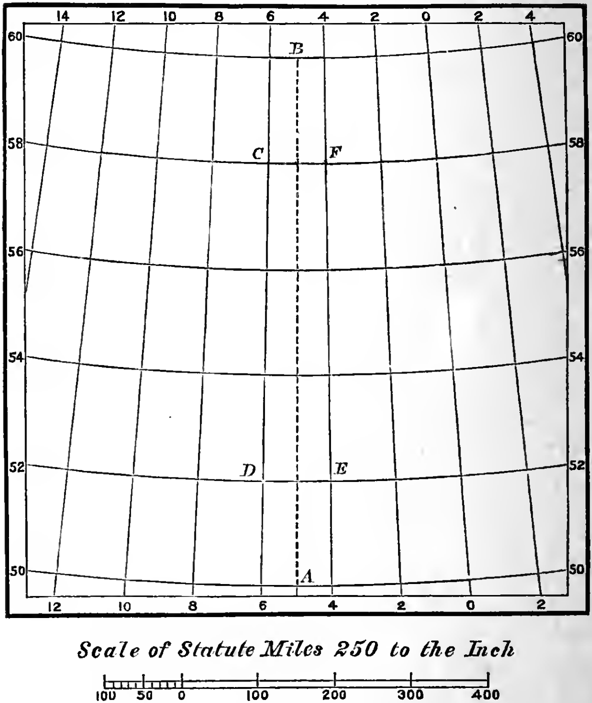


Fig. 27.—Construction of Map on the Conical Development.

the tracing-paper over and over, prick through it with a needle-point the intersections of the lines,

then join them, and continue in the same way till the network of latitudes and longitudes is complete.

As we have drawn our network, the parallels are a series of short straight lines, whilst they should be arcs of a circle. To draw them so, we can produce meridians far apart to meet. Where they meet is the centre of the circle. We can now draw the arcs correctly, as in Fig. 27.

In an Appendix will be found a table of the distances apart of meridians at different latitudes, to enable the student to draw out networks of latitudes and longitudes for any country or part of a country he requires, or for drawing them on the Mercator's Projection, which will next be described.

Cylindrical Development. — If instead of twisting the paper into a cone, we roll it into a cylinder, we shall obtain a different projection for our map; and near the Equator it will be a very good method (Fig. 28). It can be applied, however, with less advantage at other latitudes, for evidently it is only near the Equator that the touching cylinder approaches very close to the sphere, and at any considerable distance from it the distances apart of the meridians will be much exaggerated. This holds true also, though not to so marked a degree, if we suppose the cylinder to cut the sphere at the middle parallel of any strip between the two parallels which form the north and south boundaries of the map.

The great advantage of this method is that both the parallels and the meridians are straight

lines; and this was so convenient for navigation that nautical charts were in early times thus drawn. Mercator, however, made a great improvement upon it by taking the meridian lengths for a degree at each latitude, at the correct length for the distance

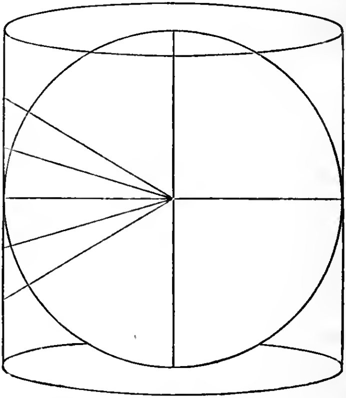


Fig. 28.—Cylindrical Development.

along a parallel. Thus, at the latitude 40° N., since the distance between meridians 1° apart is 52·9 miles, the distance apart of two parallels would be made $\frac{690}{529}$ of its length at the Equator. At 60° N., where the meridians would be 34·5 miles apart, this length would be $\frac{690}{345}$, or twice the length at the Equator; and every line about this latitude would be on the map double the same distance if drawn near the Equator.

This great variation in scale renders maps on the

Mercator's Projection very deceptive to the eye. Greenland looks larger than Africa, and Alaska nearly as large as the United States. It is not, however, so deceptive as the cylindrical, for in that method the countries are quite drawn out of shape, as well as made much too large.

For charts the Mercator's Projection is now always used, because it has the great advantage that all rhumb-lines are straight lines; so that the navigator has only to draw a straight line on his chart from port to port to know what course he is to steer.

Summary.—Each of the chief projections has now been considered, and before proceeding to the details of maps, it will be well to notice the conclusions to which we have come. For a map of the world, we should choose the stereographic, or the globular; which we should use also for maps of continents. For a map of the polar regions we might with advantage take the orthographic projection, but should prefer the stereographic. For a country not extending far from the Equator, such as Equador, the cylindrical would be convenient; but for ordinary maps of countries we should without hesitation prefer the conical to any other. Mariners' charts would be drawn to Mercator's Projection. These rules are now mostly adopted by the publishers of our atlases, but it seems a pity that they do not state on each to what projection it is drawn.

Drawing the Map.—First of all the scale must

be drawn, and then the network of latitudes and longitudes constructed. Next the points in the country whose latitudes and longitudes have been astronomically fixed are marked, then the stations of the chief triangulations, and finally the details are drawn from the plans of the surveyors.

These will have been made on a much larger scale than that of the map, and therefore the method of diminishing and enlarging maps may be here explained. Supposing the scale of the plan of details has been six inches to the mile, and the map is to be one inch to the mile, the surface of the paper on which it is to be drawn will be covered with small squares formed by drawing in pencil parallel lines equally distant from one another, and by another series at right angles to them. The plan is covered also with similar squares, but with sides six times as large. It is then easy with these lines as guides to draw the map.

If the plan must not be marked, several devices are made use of. Sometimes the lines are marked on a sheet of glass, which is laid flat on the plan, and sometimes a framework of wood has threads stretched across it to form the squares. Lately photography has been much used for copying maps on a diminished scale. The sheets of the Ordnance Survey on the scale of six inches to the mile have thus been reduced to the one inch scale.

With small scale maps, unless great accuracy is required, the squares will not be needed, as the

meridians and parallels will be sufficient guides; but if they are very far apart, or if the difference in the scale of the original and copy is great, they will be found necessary.

The **Pantagraph** is a very ingenious instrument, constructed of straight rods of wood hinged together, so as to enable a plan to be drawn on an enlarged or diminished scale, but though useful for many purposes of enlargement or reduction, it is hardly exact enough in its working where rigid accuracy is required.

Symbols used in Map-drawing.—A few observations may be made on the symbols that are used to represent various objects. They have varied from time to time, but we need not trouble about those that have gone out of use. There are two distinct classes of maps, however, in which symbols occasionally differ, namely, maps on a large and on a small scale. Most of these differences are so familiar as to need no remarks, but some are so important as to be worthy of some attention. The most essential of them is the method of expressing differences of altitude.

Contours.—In plans and maps on a large scale at the present day contours are shown sometimes by dotted black lines, sometimes by red lines. The same method of representing heights is being gradually extended to maps on a much smaller scale; for it gives far the most accurate information, and can be readily understood by any one after a little prac-

tice, though it demands close attention before its full meaning is grasped.

As a rule, the number of feet above the sea-level expressed by each contour-line is printed at intervals along the line; so that if we see 200 on one, and 300 on another line next to it, we know that the ground is generally rising from the former line to the latter. The chief confusion likely to arise is from the complicated way in which the lines wander about over the map, especially in a country which is only undulating and not actually hilly. The best plan to understand the undulations is to start with the lowest ground on the map, which can always be found by observing where the rivers run off it, or noticing the sea-line, if the map extends to the sea; then to find the first contour-line above it, and follow it round as far as possible; after that to take the next, and so on, till the highest that appears on the map is reached.

A few important points deserve to be remembered. Where the slopes are steepest the contour-lines are nearest together, while if the land is nearly level they are far apart. Between two contours we often find a contour-line forming a ring with perhaps one or more rings within it. This indicates what is called a sub-feature—that is, a prominent knoll or small hill standing up from the side of a larger one.

Next we frequently meet with several contour-lines within one another, running almost parallel for some distance, and then turning sharp round and

returning nearly parallel to their former course. This will mean one of two things, either that there is a spur of high ground extending out into the lower ground, and forming what is called a watershed, or that there is a hollow or watercourse. To determine which it is, we must look at the contours. If the highest is the inner one, it is a ridge of high ground, if the lowest is the inner, it is a valley or ravine. Of course, if a stream is marked as running down it, we know at once that it is a hollow. Again, a little examination will show that in the case of every river or stream the contour-line nearest to it on each bank is always part of the same contour.

The illustration (Fig. 29) shows a piece of an imaginary contoured map, and it can, by means of the above rules, be read easily. The river runs off the map at A, which is thus the lowest point on the map; the contour-line nearest to it on each bank is the lowest contour-line—we will call it 1, the one next to it 2, and the third 3; next we have contours 4 and 5 just appearing on the upper or north edge of the map.

We notice first that the contour-lines on the north side or right bank of the river are closer together than those on the south side. This difference teaches us that the ground is more hilly on the north than on the south. Next we observe that the three lowest contour-lines first of all curve northwards, and then bend down again southwards, and that contour 1—the lower line—is the inner one. Here, therefore, must be a hollow. After this bend,

these three contours stretch down towards the curve in the river, and then return in a north-westerly direction, the highest being the inner. Here, on the other hand, must be a spur. On this spur, and lying

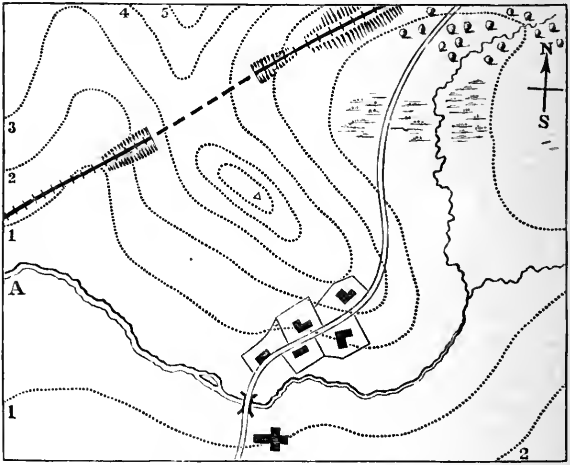


Fig. 29.—Piece of a Contoured Map.

between the lines 3 and 4, one ring placed within another shows where a hill rises upon the spur.

Before we could thoroughly understand the slopes, we should have to know the scale of the map and the interval of height between the contours, or as they are called, the *vertical intervals;* these are seen at once when a scale is drawn and the contours have their heights marked on them.

If on our illustration (Fig. 29) the contours were

20 feet apart, and the scale six inches to the mile, which is the scale employed by the Ordnance Survey for the county maps of the British Isles, we should know at once that the knoll was 80 feet above the lowest contour; and, as we could measure by our scale the intervals between the contours, we should know exactly the slope of the ground at any point. Suppose, for instance, the breadth of ground between two contours to be 40 yards, the slope would be 20 in 120 feet, or as it would be called, 1 in 6; and the angle of slope would be found to be about $9\frac{1}{2}°$.

Contour-lines are drawn on the last edition of the one-inch-to-the-mile Ordnance maps of England. The lines given are those at 50, 100, 200 feet, and so on up to 900 feet, and then at greater intervals. They are, however, printed with such very fine dotted lines, that they are often difficult to follow except with a magnifying glass. Sometimes small portions of intermediate contours at important places are also given, which go by the name of *form-lines*, and besides this, the exact height of numerous spots, especially the tops of hills and stations in the survey, are inserted; these are generally marked with a Δ, and the height in feet is printed close to them.

Hachuring.—As contour-lines do not strike the eye at once and give the general form of the country at a glance, and as, moreover, they demand some little attention and practice in their use, other devices have been made use of to show up the heights. The

ordinary system is by "hachuring"—that is, by shading the map dark for steep, and light for gentle slopes. The shading is expressed by lines, and in two ways. Vertical hachuring consists in drawing the lines in the directions in which water would flow from the higher ground—that is, perpendicular to the contour-lines. Horizontal hachuring, which is now nearly given up, is done by drawing the lines parallel to the contour-lines. The illustration (Fig. 30)

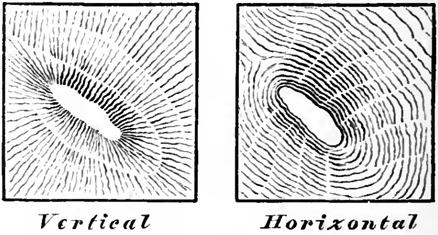


Fig. 30.—Expression of Heights on Maps by Hachuring.

shows the knoll on the spur in the preceding figure shaded roughly according to these two methods.

Mezzotint Shading.—A good way to produce an effective style of shading consists in scraping a little lead from a pencil and rubbing it over the slopes with a piece of wash-leather. After a little practice, this can be done quickly and accurately; and, as it is a transparent shade, all printing on the map can be seen distinctly through it. To prevent rubbing, it should be washed over with thin gum-water. Another effective plan is to wash in the

slopes with Indian ink or sepia. This produces much the same effect as the pencil dust, but perhaps requires more skill, and is not much used in England.

Hitherto we have been dealing with large scale maps. On those of countries or continents it is impossible to show any elevations less than mountains, or ranges of important hills; these in our atlas maps are represented by vertical hachuring, with the darker shading usually on the steeper side. Unfortunately, the system of expressing watersheds as ranges of mountains, and of making the latter continuous undulating bands like processions of caterpillars walking over the map, is not yet extinct.

Rivers are represented by a single line if they are small, and by a double line when they broaden out and become navigable; they are in the best maps printed in blue. Indeed, water is generally shown by a thin pale wash of blue darker towards the edges. Roads, if fit for heavy work, are usually represented by a double line, rough country roads by a double dotted line, and footpaths by a single line. Railways are sometimes drawn as a plain broad line, sometimes with short transverse lines crossing the broad line if they are double, and a plain broad line if single. In military maps the broad line is red, the cross ones black.

Upon large scale maps towns and villages are generally shown by groups of small black rectangles to represent houses or blocks, but in small maps by circles with centres for cities, plain circles for smaller

towns, and sometimes only dots for villages. But these symbols vary with the taste or needs of the cartographer. First-class fortresses are often represented like cities, with several short rays from the circumference, and smaller ones as towns with only four rays; and very large cities are often shown, if the scale of the map allows, by shaded blocks resembling their form. Battlefields are not infrequently marked by crossed swords.

On the piece of contoured map (Fig. 29) will be seen a railway passing through a tunnel, with a cutting just before and after it, and leaving the map on an embankment. It is to be observed that to distinguish between the two last the shading is heaviest at the higher ground; hence for an embankment it is darker next the line of railway, for a cutting lighter. There is also introduced a road passing over a bridge, with a village and church. Near the north-east corner is a wood, and between it and the centre swampy ground. These are drawn on the supposition that the scale is about six inches to a mile; if the scale were smaller, everything would be shown smaller, and much might require to be left out.

In charts, the lines of equal depths near the shore are marked by dotted lines like contours, but the numbers are given in fathoms. Shoals are usually shown by the space they fill being covered with minute dots. Small anchors mean that there is a good bottom for vessels to ride at anchor.

In the Ordnance Survey maps no sign is shown for the points of the compass, for it is always understood that the top of the map is North, the bottom South, the right hand East, and the left hand West; but generally on plans on a large scale an arrow or some similar sign is drawn to show true north. The deviation of magnetic from true north is also sometimes expressed, and always on the Admiralty Charts. On atlas maps this is impossible and useless, as the meridians and parallels tell the true directions at each point, and the magnetic north will vary in different parts of the map.

Use of Maps.—We shall now go on to note how the student is to use his maps. There are two divisions of the subject, viz. for study and for reference.

(*a*) *For Study.*—In learning geography the idle and useless way is to get by rote the facts given in the geography text-book, without any or with a very slight reference to the atlas. The result of this method is that in a very few days what has been learnt grows vague, and in a few weeks is forgotten. The right way is to look upon the map as the essential object, and the text-book as a commentary and guide to it.

The position of the country to be studied should first be noticed carefully on the globe, to see how it stands with respect to the world; then on the map of the continent to which it belongs, to see what are its neighbouring countries and seas.

After this preliminary inspection we can turn to the map itself, and first study its physical features, its coast-line and boundaries, its size and general form, its mountain chains and river and lake systems, and its plateaus, plains, and deserts.

Then we may pass to its political geography. We mark where the great cities stand, and how they congregate in certain parts of the map, showing where population is thickest. Our text-book will tell us the reason of this distribution of the inhabitants—how, for example, Lancashire gathers millions about the cotton-spinning factories; how Staffordshire swarms with ironworks and potteries; how Belfast and the towns around thrive on the linen trade; how Lyons and its neighbourhood are busy with the silkworm and its produce.

We shall next notice the internal means of communication—the roads, railways, navigable rivers, and canals; and observe how by seaports the country is connected with other lands. To study geography in its fullest sense we must know much history; many a little town rouses stirring memories. Arbela is hardly marked on our maps; Marston Moor and Culloden are bare heaths, and Waterloo but a hamlet. Study a map rightly, and we shall not forget it; it is no longer a string of dry names, and drier statistics; but a tale of man's doings to-day and of old, and of nature's work through the ages.

(*b*) *For Reference.*—Maps must be always at hand for reference. No history or book of travels or

even tale of adventure should be read without them, each place whose name is unfamiliar to us should be looked out; and so both book and map will be printed on the memory; and we shall understand what we read much better, and take infinitely more interest in it.

V.—COPYING MAPS

As copying maps is an exercise much attended to at the present day, we shall now treat of it somewhat fully.

A few general observations may be made at the outset. Map-drawing must not be done in a hurry; neatness and care are the first qualities wanted, and practice will improve them and teach speed. Next the student must understand that he is not the skilled draughtsman who has etched the map to be copied, and that he can neither do the work as well nor spend the time on it that a man does who lives by drawing maps.

The question then for him is, to arrive at the best result possible considering his inexperience and limited skill and time. We shall go through the process of drawing a map and explain each step, and the means to be taken to diminish the labour, and bring it within the reach of the ordinary student. We take a map of a country on the conical projection.

The learner will first lay down his network of latitudes and longitudes. The simplest plan will be

to begin by drawing the boundary-lines of his map, measured very carefully, to make sure they are exactly equal to the original. Then he should place an edge of paper against the upper side of the map, and mark on it with a finely-pointed pencil the points in which the meridians meet the edge, and transfer these to the corresponding line in his own. He will do the same round each side of the map. Then he should rule the meridians, beginning at the middle ones and proceeding to the edges, and marking along each the points where the parallels cross them. He should draw these parallels at straight lines from point to point as a rule, for the difference between the straight lines and the circular arcs is very slight, and he will have much difficulty in drawing them as arcs of circles, with a very good chance of failing to get them right after his best efforts. These lines should all be drawn with a mathematical pen and Indian ink, and made as fine as the pen allows. The numbers of the degrees should be next printed along each side as neatly and clearly as possible.

He now proceeds to the outline. Beginning at the top of the map, he observes where the outline crosses the lines of network, and marks the places with a pencil; he then draws roughly the outline between two consecutive points, being careful to see that he has caught the general curves of it, but with no detail. He continues pencilling out in this way the whole outline. He will often find it well to measure the distance of important points from the nearest

lines. It is best to draw the whole outline thus before inking in the details, because it will often be found that he will see little errors when he has a general view of the whole which he did not perceive when he had drawn only a little bit; besides, as some time passes between the first pencil drawing and inking, the eye will, as it were, have lost the first impression, and will be more likely to see where that first notion was faulty.

He now draws in the details with an etching-pen and Indian ink, keeping his line as uniform in thickness as possible. Little faults in these details are not important, but every headland and river mouth must be accurately at the right place. The boundary line between two countries may be dotted; but it is more rapid, as effective, and much easier to draw it in what is called chain, that is a broken line.

The next step is to draw in the rivers by carefully noting where they cross the respective meridians and parallels. As with the outlines, the general course of one river and its tributaries should be carefully drawn in pencil without the small twists, and then inked in with the details in blue ink before going to the next river basin. Here the student is advised to miss the very small tributaries, whose names he cannot insert; and from this point he will begin missing details which he could not put in well. It is no use to draw what he cannot find room to name, for he will soon discover when he begins to print in names that he cannot do this neatly

enough to enter without confusion all he finds in the original map.

He comes now to the mountains; and to these he must give great care and apply all his skill. Far the best plan for him to pursue is to draw the outline of the crest in pencil carefully from the map, and then to shade the slopes with a pale wash of sepia or Indian ink, imitating as nearly as he can the depth of colour of the copy. The usual fault is that they are made much too dark, and so spoil the effect of the whole map. If he is anxious to try hachuring, little as it is to be recommended, the Indian ink should be mixed rather thin, as the result then is not so heavy. The rule to be followed is to draw each hachure at right angles to the crest line, and not to let the hachures meet one another; but at its best, in the hands of any but skilled draughtsmen, the work will be slow and tedious, and the result disappointing.

The towns will be next put in, and first all the important cities with their names in pencil, to see what space the printing will take, then the smaller ones, where there is room for them; but the golden rule here is to put in no more than can be shown without crowding or indistinctness. It will be probably best to draw in the large places as small circles and the smaller as dots. The railways and roads may next be inserted, the former shown by rather thick, and the latter by single thin, lines; double lines are difficult to draw well and take a long time.

Now comes the printing in of the names; this requires great neatness, and cannot be successfully done until after some practice. The names of towns should be horizontal, those of rivers and mountain chains should extend along the courses at convenient places. The student should avoid printing too small. He will be able to write in a small space if he does not slope his letters too much, and places them close together. A pencil line should be drawn to keep the names straight. Heavy printing in large capitals across the map is to be avoided as much as possible.

The next step is colouring; but little of this is necessary, except a very light wash of blue over the water, slightly darker along the shores. The learner must be on his guard against putting colour over ordinary writing ink, for the latter will "run," that is, will become blurred. The great advantage of good fresh Indian or China ink is that it may be coloured over without injury; hence it should always be used in map-drawing when any colour or tint of any kind is to be put on the map with a brush.

In maps of continents, each country should be marked round with colour, which should be quite light in tint, and put on with a soft brush without any rubbing. The beginner will find some difficulty in washing over a large space with a uniform shade. A good plan is to slightly damp the whole surface to be so covered with clean water before applying the colour.

The map we have been considering is that of a

single country with a conical projection. If a copy has, however, to be made of a hemisphere or continent, we shall have to draw the lines of latitudes and longitudes differently. The projection will probably be the globular, and in explaining it we have already seen how it is constructed. Both the meridians and the parallels will be arcs of circles, and as such they must be drawn.

In the construction of such a map we proceed as before to mark the points on the edges of the map, and then after fixing the paper on a large board with drawing pins, we draw the centre meridian straight; along it we mark the points where the parallels cut it; then by trial find the centre in the meridian produced, so as to pass through each point in the meridian and the corresponding points on the edge; and draw the circles. Then mark along a central one of these where the other meridians cross it, and find the centre for each of them by trial, so as to pass through these points and the corresponding ones on the north and south edges of the paper, remembering that these centres will always be on the Equator. Drawing these circles will be found a troublesome matter. The one centre only for Europe, Asia, and North America, and for the other continents two centres not very far from the map, will give us the latitudes, but there will be a different centre for each meridian, and some of them will be very distant.

The following device will help in drawing the

circles (Fig. 31). Fasten two strings firmly to the drawing-pen or pencil, one near the point, the other a few inches from it, so that they cannot slip, knot them together at a little distance from the pen, so that when the one nearer the writing point is horizontal,

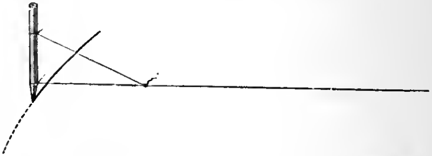


Fig. 31.—Method of drawing Parts of Circles on a Map.

the pen may be vertical; let one end be cut off, and the other be long. Hold the pen over the middle point through which the circle is to be drawn, and with the other hand stretch the string to about where the centre will be, press the thumb nail on it to keep it fixed, and then measure to the other points. By shifting the centre a trifle nearer or farther the true centre will soon be found, and the circle can then be drawn. The pen must be carefully held vertical and the strain on the string kept uniform, or it will stretch and spoil the curve. Some draw the meridians by marking all the points on the latitudes, and then using as a ruler either a French curve or a cane or pliant wood bent to the arc required.

In filling in the details of these maps no further information is needed, but it is usual to print the names of towns parallel to the latitudes.

It is important to choose properly the map to copy. Let it be one clearly printed and without too many details; what looks an empty map is far best for study and for copying, however valuable for reference the more elaborate maps may be. Butler's *Public School Atlas* will suit perfectly, and there are many others now published which will do as well.

Use of Map Copying.—Undoubtedly copying maps has great uses. It trains the eye and the hand admirably, it teaches care and patience, and it makes the form of countries and names of places to a certain extent familiar; but on the other hand it costs much time, and does not teach geography or a knowledge of maps to anything like a corresponding extent. It is very well to draw a few, and every one should do so, but there are other methods so much more effectual, that in the interests of real map-learning we are inclined to grudge the many hours spent in mere mechanical copying. To prove this, let any one who has worked for days at an elaborate copy of a map, try a week afterwards how much of it he can reproduce from memory, and he will find it will not be as much as he could learn in as many hours on another system.

VI.—MEMORY MAPS

Their Importance.—We have seen how maps are to be studied with the aid of the text-books, and now we shall consider how this may be carried much further, and how the important details may be so fixed in the mind that we can reproduce them at will.

We can all recognise a portrait, and judge whether a likeness is correct or not, though there are very few who can themselves draw one. It is the same with maps. We are familiar with them from our atlases; and if we saw a badly drawn one we should know at once that it was wrong, but most of us could not ourselves correct it, nor draw a better without a correct map to copy. The object of the following pages is to show how a more accurate knowledge of maps can be learnt.

A correct eye for drawing will of course be a great help, but the poorest draughtsman with a little extra trouble can attain sound knowledge and considerable facility in drawing maps from memory, if he only goes to work in the right way.

What to remember.—First, we must clearly understand what we want to do. We wish to fix the general shape of a country correctly in the mind, not vaguely, but so that we can not only recognise it when we see it, but can draw it at once on paper; we must be able to show in their true relative positions all the chief capes and river mouths, to trace the rivers to their sources, to determine the crest lines of mountain ranges, and to give accurately the position of important towns. And here we must be sure what constitutes geographical importance. Mere size is not the test, much less the size of the printing of the name on the map; a place is to be remembered because the world talks of it, because it is a centre of civilisation or trade, because it is associated with some great fact in history, or has been the birthplace or home of some hero of whom the world is proud.

How to proceed.—Several methods of drawing maps from memory have been suggested and practised. Drawing over and over again a very much simplified outline is commonly tried with some success, but the disadvantage of this method is that when we have fixed the form in the memory, as we think, we shall go on repeating it, and a little error will creep in here and there and we shall fix this error as strongly as the correct parts, and let it grow upon us till the whole map becomes seriously distorted.

It seems then necessary to have certain fixed lines to guide us, such as we can measure, so that we

cannot go far wrong. Taking latitudes and longitudes simplified into straight lines has been tried; but, besides the great difficulty of remembering where the outline cuts them round even a single country, and still more, round fifteen or twenty maps, there is the disadvantage, which appears fatal, that altering the meridians and latitudes actually teaches us to misdraw the map. The vague resemblance of the outline of a country to familiar forms, Italy to a leg and foot, South America to a leg of mutton, the Morea to a mulberry leaf, is of no use to us; it may help little children to form some notion of the form, but will not aid us to draw correctly.

There are certain geometrical forms familiar to all, such as the square, triangle, rectangle, and circle; and a little ingenuity will enable us to find some combination of them which approaches very nearly to the outline of any country. This is the method I approve of, and which I now wish to explain.

Take a map of small value, that we do not mind spoiling, and try experiments on it; those in a shilling atlas will be good enough. At first we must choose one with a simple outline—the simplest are Spain, South America, Africa, or France. Suppose we have chosen the last.

With a pair of dividers or an edge of paper we measure some clearly marked distance, and try this about the map to see whether it is repeated in other places. After a time we shall notice that the general form of the mass of the country is square, with the

northern part projecting above, and the Brittany peninsula to the west. We shall next have to determine how to fit our square in, so as to lie as near as possible to the coast, and have important points at the angles. The corner of a sheet of note-paper provides us with a right angle, and we shall find that if we place this corner at the Spanish frontier on the Bay of Biscay two sides of equal length reach Toulon to the east, and St. Malo to the north. We draw these two, and finish the square, giving us the fourth corner at Nancy on the Moselle. We find this comes pretty near the border on three sides, and we observe that the coast-line cuts the south side at one-third the distance from Toulon.

We now examine the northern part, and try for some way of making a triangle fit it. We notice that Dunkirk is nearly due north of the middle of our square. Our first attempt will probably be by drawing a perpendicular from the centre of the upper side of the square, and we measure the length along this to the boundary. This distance we shall find to be less than half the side of the square, so that if we make it exactly half, our triangle departs too much from the form required. If, however, we take the sides for our triangle as two-thirds the side of the square, we shall have a good form for it.

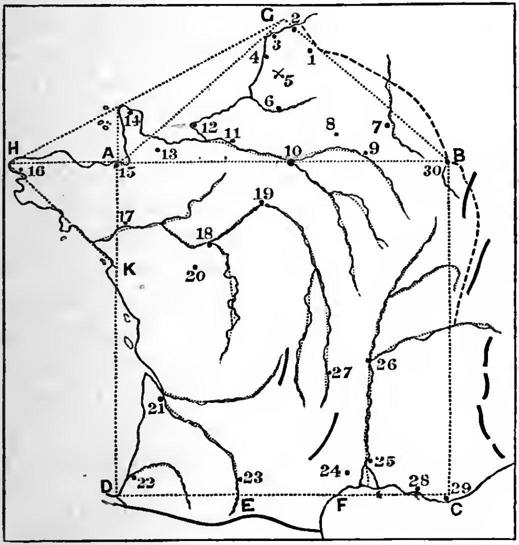
There now remains the Brittany peninsula. The side of the square produced evidently gives the north of it, and if we measure its length we shall find it just a third of the side of the square. The same

distance along the other side of the square brings us to a point which, when joined with the extreme point of the peninsula, gives us a fair southern boundary for it.

We draw all these lines on the map, and observe where the outline varies much from what we may call our guide-lines. We notice first that the west end of the Lake of Geneva is halfway along the eastern side of the square, and that the mountain boundary of France and Italy is considerably to the east, though nearly parallel to the guide-line; the frontier from Geneva to Nancy forms an arc beyond the guide-line, and so does the frontier from Nancy to about Lille. On the other side we notice that La Hogue on the Cherbourg promontory is at the point where the side of the square produced meets the line joining Ushant with the vertex of the northern triangle. The coast between Dunkirk and Cherbourg will require a little practice to learn. Bordeaux is nearly a third of the distance up the west side of the square, but at a considerable distance from it.

Now we shall begin to draw. First we make a square ABCD, with its base horizontal (Fig. 32). This base we divide in three equal parts in the points E and F; then draw an arc with the centre A and radius DF, and another with the centre B and the same radius, to cross one another at G; we now join GA and GB, and produce BA to H, making AH equal to FC, cut off AK also equal to AC, and join HK. The guide-lines are now complete, and must be learnt; doing

them roughly without measurement except by the eye two or three times, which will take but a few minutes, will effect this.



This map does not show

Fig. 32.—Map-drawing from Memory—Scheme for Map of France.

Take next a carefully-made set of guide-lines, and draw on them an outline of the map, not giving all details, but merely copying the general outline, not forgetting the chief islands. To make sure that this is sufficiently simple and yet accurate, a good plan is to draw it first over the copy with a bold strong line in red chalk. The special point to be guarded against

is putting in details that are not necessary to remember; on this point too much stress cannot be laid.

This must now be learnt; the outline thus drawn should be copied once or twice on the guide-lines previously prepared; and then drawn three or four times from memory, each such attempt being carefully compared with the correct one. This will be found enough, and we shall now have the outline fixed in the mind and eye.

The next point is to learn the rivers. They are drawn similarly. Mark in red on the printed map the general course from one point of importance to another, beginning at the mouth and tracing up to the source; and in the same way with the chief tributaries which we desire to remember. Then draw these general lines (which will form guide-lines for the rivers) on the outline maps, and learn them by as many repetitions as may be needed. Now draw in their courses with more particulars, noting only prominent twists and curves.

The crest-line only of the mountains should be drawn and expressed by a thick black line; no slopes should be attempted. The illustration shows what we have now arrived at. The dotted lines should always be in pencil, and the outline should also be so drawn first and then inked in; after this the guide-lines in pencil may be rubbed out, and we have the physical features of our memory map complete.

There now remain to be filled in the political features, which will consist almost entirely of the

towns; and here the student will meet with the greatest difficulty. The first dozen places in any country are easily determined by the aid of a geography text-book, but great judgment is needed to choose others. Twenty or thirty towns at most should be inserted at first, and in the selection the advice given a few pages back as to what constitutes importance must be attended to.

We give a selection for France, with numbers corresponding to the numbers at the dots on the map, and the reasons for their selection; but it must be understood that this list is very incomplete: it is only a first selection. When these and the other maps and similar selections of places are learnt, the lists should be supplemented by as many more before the student can consider himself to be well advanced.

The towns are not numbered in the order of their importance, but so as to render them easy to find on the map.

1. *Lille*, a great city and fortress, the centre of a large linen, lace, and thread manufacture; captured by the English and their allies in 1708.
2. *Dunkirk*, a port surrendered to England in 1558, and held by her till it was sold by Charles II, 1662. It was gallantly and successfully defended by Hoche against us in 1793.
3. *Calais*, port on the chief route from England to France; held by England from its capture by Edward III in 1347 till its loss in the reign of Mary, 1558.

4. *Boulogne*, a watering-place and port much frequented by English, where Buonaparte collected his forces to invade England, 1804.
5. *Agincourt*, the scene of the memorable victory of Henry V in 1415.
6. *Amiens*, noted for its fine cathedral, and the treaty of 1802.
7. *Sedan*, known for cloth-making, and as the scene of the surrender of Napoleon III to the Germans with his whole army.
8. *Rheims*, in whose cathedral the kings of France were crowned, is the centre of the champagne wine trade.
9. *Chalons*, the great military camp of France, very important in her history for the victory of Theodoric over Attila, 451.
10. *Paris*, the capital, and the second city of the world, to which gather French art and science, with over $2\frac{1}{4}$ millions of people.
11. *Rouen*, the beautiful capital of Normandy, with her cathedral and churches; where Joan of Arc was burnt, 1431.
12. *Havre*, a great seaport, often bombarded by the English.
13. *Caen*, with its fine spires, and its quarries. Here William the Conqueror was buried.
14. *Cherbourg*, a great naval port, arsenal, and fortress.
15. *St. Malo*, a port with the highest rise of the tide in the Channel; has been often attacked by the English.
16. *Brest*, a great naval and trading port.
17. *Nantes* has great trade; here religious liberty was given by Henry IV, 1598, and withdrawn by Louis XIV, 1685.
18. *Tours* has important cloth and silk manufactures; here Charles Martel defeated the Saracens and drove them back to Spain.

19. *Orleans*, a great railway centre, with a fine cathedral. Joan of Arc raised the English siege, 1429.
20. *Poitiers*, where the Black Prince defeated and captured King John, 1356.
21. *Bordeaux*, the greatest French port on the Atlantic, with great trade in wine.
22. *Bayonne*, a fortified port besieged by Wellington in 1814. Here bayonets were invented.
23. *Toulouse* has large trade and cannon foundry ; here Wellington fought Soult, 1814.
24. *Nimes*, a large town with fine Roman remains.
25. *Avignon*, with wine trade, often inhabited by the Popes in the 14th century.
26. *Lyons*, the second city of France, the centre of the silk manufacture.
27. *St. Etienne ;* its ironworks make it the Birmingham of France.
28. *Marseilles*, the greatest seaport of France and of the Mediterranean ; a very ancient city, founded by the Phœnicians.
29. *Toulon*, the French Mediterranean naval port.
30. *Nancy*, made a great fortress since the loss of Metz.

We have given these notes on the places to draw attention to the way in which the towns are to be selected. There is no use in learning mere names, and every place may be left out which is a mere name.

At first there will be a good deal of hard work in learning these details ; the best way is to draw maps on the plan given, with guide-lines in red ink, in a note-book, with numbers placed against the towns, capes, rivers, etc., and to make a corresponding list such as we have above, and with a few notes of points we wish to remember about them. After learning this up once

thoroughly, an occasional repetition of the map-drawing and of putting in the towns will be enough, provided the maps are pretty often gone over, to be sure that names have not slipped the memory; such maps, however, must have no names written in.

The work will soon grow lighter, and, after mastering a few maps thoroughly, others will be learnt in a quarter of the time. No one who has ever fairly tried this method will attempt to learn maps in any other way.

For fear of being misunderstood as to this system, we repeat in brief the points to be observed:—

First, look carefully at the map to see what figures can be made to suit it.

Second, do not be satisfied with your figures till they are simple, fit the outline fairly, and fix important points.

Third, having found them, learn them thoroughly before drawing the outline.

Fourth, simplify the outline as much as possible, so as to keep the general form quite correct; learn it thoroughly before proceeding.

Fifth, draw the rivers and mountains at first with simple lines, showing the general directions, and learn them.

Sixth, insert few towns, but important ones.

Seventh, repeat often, and at intervals of time.

One advantage of this method is that it can be carried to any degree of accuracy. But beginners

must not attempt great precision. They must be satisfied with simple figures easily remembered, even though these may not give as many details as they would desire. If they try to work up three or four maps elaborately they will neglect the others; and it is of the first importance to gain a good sound knowledge of general geography, accurate as far as it goes, but not entering into details, as that will form a foundation on which they can build to any extent afterwards.

Having given this warning, we may now show how a more minutely correct map can be drawn; and as probably the first country the student would wish to study exactly will be England and Wales, we choose it (Fig. 33).

Draw a line AB at an angle of 15° to the bottom edge of the paper, and divide it into two equal parts in C. Divide AC into ten equal parts. This line will form a very good scale for drawing the map. Through C draw CD, parallel to the sides of the paper, and make it equal to AB and one-tenth of AC besides. As this length, a tenth of AC, will be constantly used, we shall call it *a*. Join AD and BD. The triangle ABD is the key to the map.

Divide AD into seven equal parts, of which AE, EF, and GD are each two parts, and FG therefore one. Through G draw GH parallel to DC. Through K, the middle of AC, draw a perpendicular with $KL = a$, and $KM = 3a$. Draw MN perpendicular to GH; join AM and L to points at distance *a* on each side of

K. Through E draw a perpendicular to AD, meeting GH, and with EO $= a$. Through P, the middle of

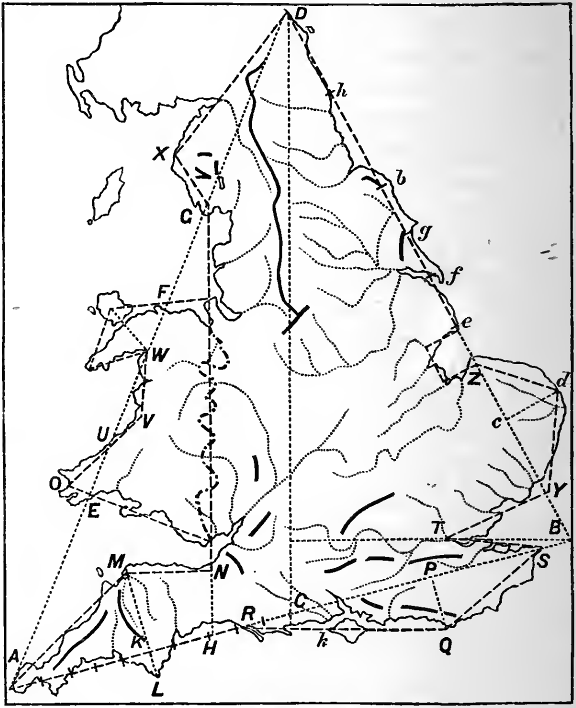


Fig. 33.—Memory Map of England and Wales.

CB, draw PQ a perpendicular $= 2a$, make CR $= 2a$, and BS $= a$. Through B draw a perpendicular to CD; its middle point T is London.

This would be enough, and more than enough, as guide-lines for a good map of England and Wales. Indeed, with a little practice, it is easy to draw a fair map with the triangle ABD divided up as directed; but our present object is to show how we may continue our method of geometrical construction, and to get so near the outline as to enable us to draw from memory a map which would be as good as many persons could make by copying one from an atlas. We therefore continue the construction.

Make $EU = 2a$, and produce OU to V, so that $UV = a$. Make $FW = 2a$, and draw the two equal-sided triangles shown. Join WV. Draw GX parallel to BD, and equal to $2a$. Join DX. Make BY equal to $2a$. Take Z and b, the points which divide DB into three equal parts; make Zc and the perpendicular cd each equal to $2a$. Make Ze a quarter of ZY, and draw on it a square. Let f be the middle of bZ, g the middle of bf, and h the middle of Db. Make $Hk = 3a$. Now our framework is sufficiently correct to enable us to draw a very good map.

On the illustration the final guide-lines are drawn as "chain," the other construction lines as dotted, and the final outline is given. At a first glance the construction will seem very difficult to remember, but in practice it will not be found so, because, first, the same distances occur so many times, and secondly, when we have drawn the map carefully a few times, the eye gets so accustomed to the form, that it at once suggests what the distance ought to be. Again,

if one or two of the minor measurements happen to be forgotten, it will probably have little effect on the outline, unless they are not only forgotten, but drawn wrong. As an aid to the memory we give the list of lines equal to a; they are BS, three lines from K, OE, UV; those equal to $2a$ are GX, FW, UE, RC, PQ, BY, Zc, and cd. Notice also that the chief points on the east coast are found by halving lines; and the only lines equal to $3a$ are MK and Rk.

On the map are also marked guide-lines for the rivers; and the hill ranges are marked. We have thus completed a physical map of the country quite as accurate as could be desired for a memory map. It should be drawn with all the lines two or three times as long as here given, but the size of the page allows ours to be no larger.

As the line AB is about 340 miles, each line of length a is 17 miles, and therefore we see that however inaccurate the student's eye may be, he is not likely to make anywhere an error of more than four or five miles. Any examiner in geography will acknowledge that it is very rare to obtain a memory map drawn in examination nearly as accurate as this. He commonly finds a part of a map perhaps well done, and the rest incorrect to the extent of twenty or thirty miles.

In the study of physical geography we often want a rough map of the world on the Mercator's Projection to illustrate ocean currents, isothermal lines, trade winds, centres and lines of volcanic action, the flora and

fauna of districts of the world, and for other purposes. I will therefore show how such may be drawn, and especially as it illustrates a point of much importance in the system now advocated.

It has been before stated that the student should begin with the simplest maps, and it is best not to touch Europe or Asia until most of the important countries have been mastered separately. This is even more noteworthy when we come to a map of the world, where the form of each continent must be well known. Of course for the maps required for the purposes above referred to we do not want a careful map, but it is much easier to draw the roughest if we have a good previous knowledge of the details.

Our method gives, if required, latitudes and longitudes, as will be seen below; we draw the map, however, without their aid, but with the Equator, the Tropics, and Polar Circles, which are sure to be required in any map. Such maps are often wanted in examination, but any attempt to draw then the meridians and parallels takes too much time, or proves unsatisfactory. Draw a line AB for the Arctic Circle (Fig. 34). Then on the edge of a piece of paper mark carefully fourteen small equal spaces to form a scale. These fourteen should be rather less than half the length of our map from east to west. In this diagram the object has been to give a fair view of the Atlantic, Pacific, and Indian Oceans, so that England lies a little to the east of the

middle of the map, though even then the small size of the page prevents the map being carried far enough

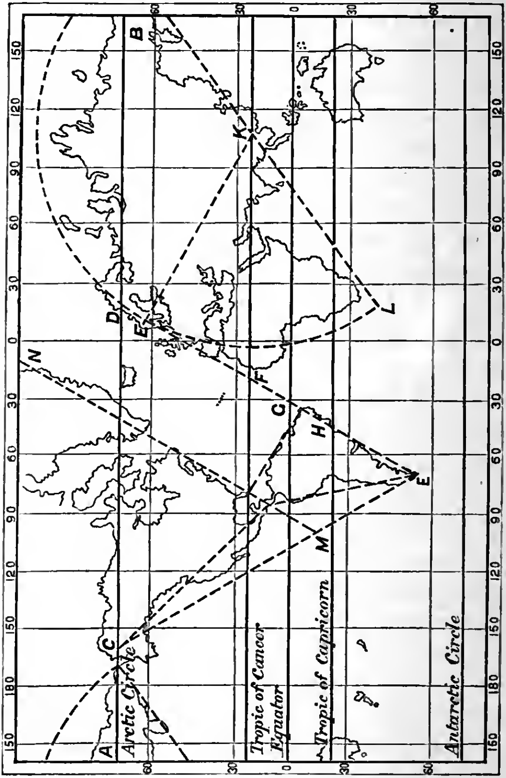


Fig. 84.—Memory Map of the World on Mercator's Projection.

to the west to show the whole of the Pacific at one glance.

First measure the length fourteen along AB, and below it describe an equilateral triangle CDE; this will contain the North Atlantic and the two Americas. From DE mark off F the sixth, G the eighth, and H the tenth division of the scale, and through these points draw lines parallel to AB; they are the Tropic of Cancer, the Equator, and the Tropic of Capricorn.[1] Now mark one division from DE, and thence draw a perpendicular to DE meeting FK in K, and with this line as radius, draw a circle to cut the line AB (this point lies beyond the illustration). Join the point thus found to K, and produce it to meet the circle again at L. This semicircle contains the three continents of the Old World.

At a distance of four divisions draw MN parallel to DE, which determines the east coast of North America. From where it cuts the Tropic of Cancer draw a line to a point in DE half a division south of the Equator; this gives the north-east coast of South America. Two divisions along MN gives Central America; lines thence to C and E give the west coasts of the Americas.

We can now draw in our outline with these as guide-lines. It will need some practice to do this well, as it is necessary to remember that the scale of our map towards the north is very much larger than near the Equator; but, however inaccurately we do it, it will probably be sufficient for our purpose.

[1] If the scale of map is large, the Tropics should be drawn slightly farther from the Equator.

If an accurate map is to be learnt, we shall want to put in the latitudes and longitudes. We draw them 30° apart. Two and two-third divisions down DE is Greenwich. Through it draw a perpendicular to AB giving us its meridian. From the Equator mark $2\frac{1}{2}$ and $5\frac{2}{3}$ of our scale north and south, and draw lines parallel to the Equator; they are the 30° and 60° parallels.

Now make a fresh scale by taking twelve divisions of the old one, and dividing it into five equal parts; mark these divisions along the Equator from the meridian of Greenwich, and draw the other meridians through these points.

Remembering a few important latitudes and longitudes will now enable us to draw a very good map. On the Arctic Circle we have East Cape on Behring Straits, the south of the Gulf of Obi (with long. 75°), the north of the White Sea (long. 40°), and of Iceland (long. 20° W.) On the parallel 60° N. we have the north of the Kamtchatka promontory, St. Petersburg (long. 30° E.), and Cape Farewell on Greenland (long. 45° W.) On the 30° N. we have Shanghai (long. 120° E.), the north of the Persian Gulf (long. nearly 50° E.), Alexandria (long. 30° E.), and New Orleans (long. 90° W.) On the Tropic of Cancer there are Canton (long. 112° E.), Calcutta (long. 90° E.), and Havanah. The Equator passes through Celebes (120° E.), Borneo and Sumatra, Victoria and Albert Nyanza (long. 30° E.), the mouth of the Amazon and Quito (long. 80° W.) The Tropic

of Capricorn crosses just north of the middle of Australia (with long. from 115° to 154° E.), the south of Madagascar (long. 45° E.), and Rio de Janeiro (long. 42° W.) On 30° S. is Port Natal (long. 30° E.)

The meridian of 70° W. is useful to the map-drawer, for near it are Quebec (lat. 47° N.), Boston (lat. 42 N.), Hayti (lat. 19° N.), Maracaybo (lat. 10° N.), part of the west coast of South America, Santiago (lat. 34° S.), and Cape Horn is 3° to the east of it with latitude 56° S.

It is worth remarking that for learning latitudes and longitudes the best map to study is certainly a Mercator; and for this purpose, if for no other, it is well worth while to learn it carefully.

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